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Future Force Warrior Integrated Analysis Planning

OPERATIONS RESEARCH CENTER OF EXCELLENCE
TECHNICAL REPORT NO: DSE-TR-0542
DTIC #: ADA434914

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Abstract

As an important part of the Future Force Warrior (FFW) program, the Analysis and Experimentation Team (A&ET) performs Systems of Systems (SoS) modeling, closed-loop simulation, Soldier in the Loop (SITL) simulation, virtual simulation, and live experimentation analyses. Within the A&ET, the Analysis Team is directly responsible for these SoS efforts short of live experimentation and demonstrations. The analysis efforts must be integrated into a larger A&ET strategy that supports FFW design and development decision making. This work provides a methodology for developing primary Measures of Performance (MOP) and Measures of Effectiveness (MOE), an Integrated Analysis and Experimentation Framework, and an Analysis and Experimentation Event Plan. The methodology and the resulting tools were developed to support the Design, Build, and Integration Phase of the FFW program. However, the general methods and techniques are intended to be useful for other Science & Technology (S&T) and acquisition programs.

About the Author

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Table of Contents

Tables

Figures

Chapter 1: Introduction

1.1 Background

The Future Force Warrior (FFW) Advanced Technology Demonstration (ATD) program is a U. S. Army Science and Technology (S&T) initiative that aims to improve soldier and small combat unit capability for 2010 and beyond. FFW is intended to complement the Future Combat System (FCS) program. The desire is to transition the most promising FFW technologies and capabilities into Army acquisition programs for development and fielding. FFW supports the Ground Soldier System (GSS) spiral fielding strategy and thus, parallels the FCS spiral fielding strategy.

Although the FFW ATD is not an acquisition program, FFW also supports Land Warrior (LW) block III. Analysis is being done to determine the appropriate capabilities to recommend for LW block III and to assess the utility of emerging technologies in improving combat effectiveness of the soldier and small combat units.

The FFW program includes three major phases:

1. Phase 1 is the Concept Development Phase. This phase involved a 9 month competitive activity to select the Lead Technology Integrator (LTI) for the following phases of the program. Phase 1 was completed in April 2003 and resulted in the selection of Eagle Enterprise as the FFW LTI.
2. Phase 2 is the Design, Build, and Integration Phase. This phase began in June 2003. In January 2005 the program was re-baselined and reorganized and the LTI management responsibility was migrated to General Dynamics C4

Systems (GDC4S). As a result, phase 2 was broken down into 3 sub-phases. These include:

a. The Systems Engineering Synchronization sub-phase (April 2005 to August 2005)
b. The Incremental Design sub-phase (September 2005 to September 2006)
c. The Build, Integrate and Test sub-phase (October 2006 to May 2007)

3. Phase 3 is the Demonstration Phase. Phase 3 is an option that may be executed upon successful completion of phase 2. If this phase is executed, it will be based upon a scope that is negotiated and agreed upon by both the Government and the LTI.

If phase 3 is executed and completed successfully, the Program Executive Office (PEO) Soldier has the option to continue the program even further with a System Development and Demonstration (SDD) phase. Similar to the case with phase 3, the SDD phase, if executed, will be based upon a scope that is negotiated and agreed upon by both the Government and the LTI.

The work described in this report took place during the re-baselining in support of phase 2, the Design, Build, and Integration Phase. The purpose of the Design, Build, and Integration Phase is to develop FFW System of Systems (SoS) capabilities that greatly improve soldier and small combat unit war-fighting capabilities. These defined capabilities are expected to help shape the Ground Soldier System (GSS) Capability Development Document (CDD) objective capabilities. The most promising and attainable technologies may be selected for early transition to PEO Soldier SDD programs. Furthermore, FFW should be expandable so that developed capabilities can enable future expansion of other emerging Soldier as a System (SaaS) CDDs (for example, air and mounted).

Because the FFW program is an S&T program, it is expected to develop technologies and capabilities that extend those that are currently being developed by existing acquisition programs. Because the FFW technologies and capabilities have not been more fully developed yet, considerable uncertainty exists about which technologies and capabilities are most promising toward increasing soldier and small combat unit capability. Furthermore, the most appropriate Tactics, Techniques, and Procedures (TTPs) have not been fully developed because the FFW design process has not been completed. Therefore simulation, experimentation, and analysis can and should play an important role in the FFW design process.

1.2 Analysis Support Purpose

As an important part of the FFW program, the Analysis and Experimentation Team (A&ET) performs SoS modeling, closed-loop simulation, Soldier in the Loop (SITL) simulation, virtual simulation, and live experimentation analyses. Within the A&ET, the Analysis Team is directly responsible for these SoS efforts short of live experimentation and demonstrations. The analysis efforts must be integrated into a larger A&ET strategy that supports FFW design and development decision making. The purpose of this work is to develop an Integrated Analysis and Experimentation Framework and an Analysis and Experimentation Plan that will support the Design, Build, and Integration Phase of the FFW program. Furthermore, the Integrated Analysis and Experimentation Framework and Plan are expected to support follow-on phases of the FFW program.

1.3 Methodology

The general methodology that we followed to develop the Integrated Analysis and Experimentation Framework and Plan included an iterative sequence of the following steps:

<u>I. Initial Phase</u>

1. Development, refinement and prioritization of the Essential Elements of Analysis (EEAs)
2. Development and refinement of the soldier functional decomposition

<u>II. Measures of Effectiveness (MOE) and Measures of Performance (MOP) Development Phase</u>

3. Development and refinement of the primary Measures of Effectiveness (MOE)
4. Development and refinement of the Measures of Performance (MOP) Hierarchy

<u>III. Integrated Analysis and Experimentation Framework Development Phase</u>

5. Capability and MOP mapping to the EEAs
6. A&ET event feasibility in addressing EEAs and Mappping A&ET Tools to EEAs

<u>IV. A&ET Plan Development Phase</u>

7. A&ET event planning

Steps 1 and 2 are the initial phase required in this work. In step 1, the EEAs provide important analysis questions that support FFW design and development decisions. Once prioritized by the FFW Program Management Team (PMT) and the FFW Systems of Systems Engineering and Integration Team (SoSEIT), the EEAs provide the basis for defining and establishing A&ET events. In step 2, the soldier functional decomposition provides background for basic functional requirements that should be considered in the A&ET events. In steps 3 and 4, common MOEs and MOPs are identified so that separate A&E events can be related to each other in order to provide a more integrated analysis approach. In step 5, capabilities are mapped to the EEAs to identify modeling requirements associated with the respective EEAs. Also, MOPs are mapped to the EEAs to identify data collection requirements that are associated with the respective EEAs. Based upon step 5, step 6 forms the basis of appropriate A&ET event identification and feasibility associated with the respective EEAs. As a whole, steps 5 and 6 result in the FFW Integrated Analysis and Experimentation Framework. In step 7, A&ET events are selected based on consideration of steps 1 and 6, input from the FFW PMT and FFW SoSEIT, and other factors. Once EEAs and the appropriate A&ET event are selected, the results of steps 5 and 6 are used to further define the specific event plans. These steps are iterative. For example, a refinement in the MOP hierarchy may give rise to a refinement in the EEAs. Furthermore, the list of EEAs, the functional decomposition, the MOP hierarchy, and the developed Integrated Analysis and Experimentation Framework may be used as tools for other A&ET analysis activities and planning and other FFW program activities.

Each of the above listed steps requires careful consideration of the following documents. In turn, the analysis results should be used as input to these documents.

1. The Training and Doctrine (TRADOC) Systems Manager (TSM) Soldier Priority List
2. The Ground Soldier Migration Roadmap
3. The FFW Spiral Roadmap
4. The GSS Capability Development Document (CDD) to include defined Key Performance Parameters (KPP)
5. The System Performance Specification
6. The FFW Statement of Objectives (SOO)
7. The FFW Exit Criteria

1.4 Report Organization

Chapter 2 of this report describes the initial phase that includes the EEA and soldier functional decomposition steps of this methodology. Chapter 3 of this report describes the MOE and MOP development phase and includes steps 3 and 4. Chapter 4 describes the FFW Integrated Analysis and Experimentation Framework development phase and includes steps 5 and 6. Chapter 5 describes the resulting A&ET planning phase that is associated with step 7. Chapter 5 also shows the initial A&ET event plan for Phase 2 of the FFW program. Finally, chapter 6 provides the summary and conclusions.

Chapter 2: Initial Phase

2.1 General

The initial phase for the development of an Integrated Analysis and Experimentation Framework and Plan includes the following steps:

1. Development, refinement and prioritization of the Essential Elements of Analysis (EEAs)
2. Development and refinement of the soldier functional decomposition

These steps provide the basis for the steps that follow and the development of the A&ET events. In step 1, the EEAs provide important analysis questions that support FFW design and development decisions. Development and prioritization of the EEAs requires input from FFW Program Management Team (PMT) and the FFW Systems of Systems Engineering and Integration Team (SoSEIT). In step 2, the soldier functional decomposition provides background for basic functional requirements that should be considered in the A&ET events. The steps required in this work are iterative. Updates in step 4, the MOP hierarchy, for example, may result in suggested updates to the EEAs.

2.2 Essential Elements of Analysis (EEAs)

The first step in this work involves the development, refinement, and prioritization of the EEAs. The EEAs are a set of questions or concerns generated through research, consideration of the documents addressed in section 1.3, and any previous IA&ET events. The EEA list describes some of the concepts which may help focus the analysis and experimentation and help determine the solution space in the various scenarios. The list is organized by issue type and should be prioritized by the FFW PMT and the FFW SoSEIT. It is reviewed and updated periodically by the A&ET and the SoSEIT as design and development decisions shift. The list contains issues that we wish to resolve or specific questions that we wish to answer in order to address the potential increase in performance that can be expected by implementing proposed FFW concepts, technologies, or capabilities. Some of the points may become more important as conclusions are drawn and some may become less important. The EEA list may help guide some of the experimentation, lead to additional issues, and may ultimately result in a better understanding of the design considerations for the FFW SoS. See [Schamburg, 2004].

Prioritization of the EEAs is based upon design and development decision making needs from the FFW PMT and FFW SoSEIT. As the design progresses and as analysis issues are addressed, this EEA prioritization may shift and is therefore, somewhat fluid. Again, the steps required in this work are iterative. Updates in other steps and developing design decision requirements may result in suggested updates to the EEAs and their prioritization.

The initial list of EEAs was developed during Phase 1 of the FFW program. At the beginning of Phase 2, the EEAs were refined and prioritized in order to help focus A&ET efforts. As part of the re-baselining effort, the EEAs have been refined further and new EEAs have been proposed by the A&ET for consideration. The EEAs span 8 FFW objective areas and over 50 EEAs have been developed for the FFW program. The EEA objective areas include:

1. Information Superiority

2. Lethality
3. Sustainability
4. Mobility
5. Embedded Training
6. Survivability
7. Flexibility and Interoperability
8. Tactics, Techniques, and Procedures

As a result of the iterative process involved in this work, the last two categories (“Flexibility & Interoperability” and “Tactics, Techniques, & Procedures”) are new categories that have been added to the EEAs. Furthermore, this process has resulted in recommended restructuring of existing EEAs to align them more with the categories above and to make them more focused so that they can be better addressed with A&ET events.

Example EEAs include:

1. What information technologies are the most important and what improvement do they provide?
2. How do sensor capabilities affect performance?
3. What is the impact of increased communications capabilities on power requirements and sustainability?
4. What are the implications of increased information from sensors on squad tactical procedures?
5. What movement rules should be used for the employment of friendly forces and the unmanned sensors?

2.3 Functional Decomposition

The second step in this work involves the development and refinement of the soldier functional decomposition. Functional decomposition is the process of subdividing a system into discrete sets of tasks which must be completed in order to meet system objectives or requirements. For this work, we are interested in the functional requirements of an individual soldier. The purpose of this is to make sure that all elements of the soldier as a system are fully recognized and defined so that alternative solutions for operational improvement may be considered. As the steps in this work are iterative, this functional decomposition can be used as input to help refine the EEAs, the MOP hierarchy, and for other purposes in the FFW program. For previous PEO Solider requirements development [Tollefson, 2004] developed a thorough functional decomposition of the soldier as a system. As examples from [Tollefson, 2004] the top level soldier functional decomposition is shown in figure 1 and the soldier communication functional decomposition is shown in figure 2. For a more complete description of this process and the resulting soldier functional decomposition, see [Tollefson, 2004].

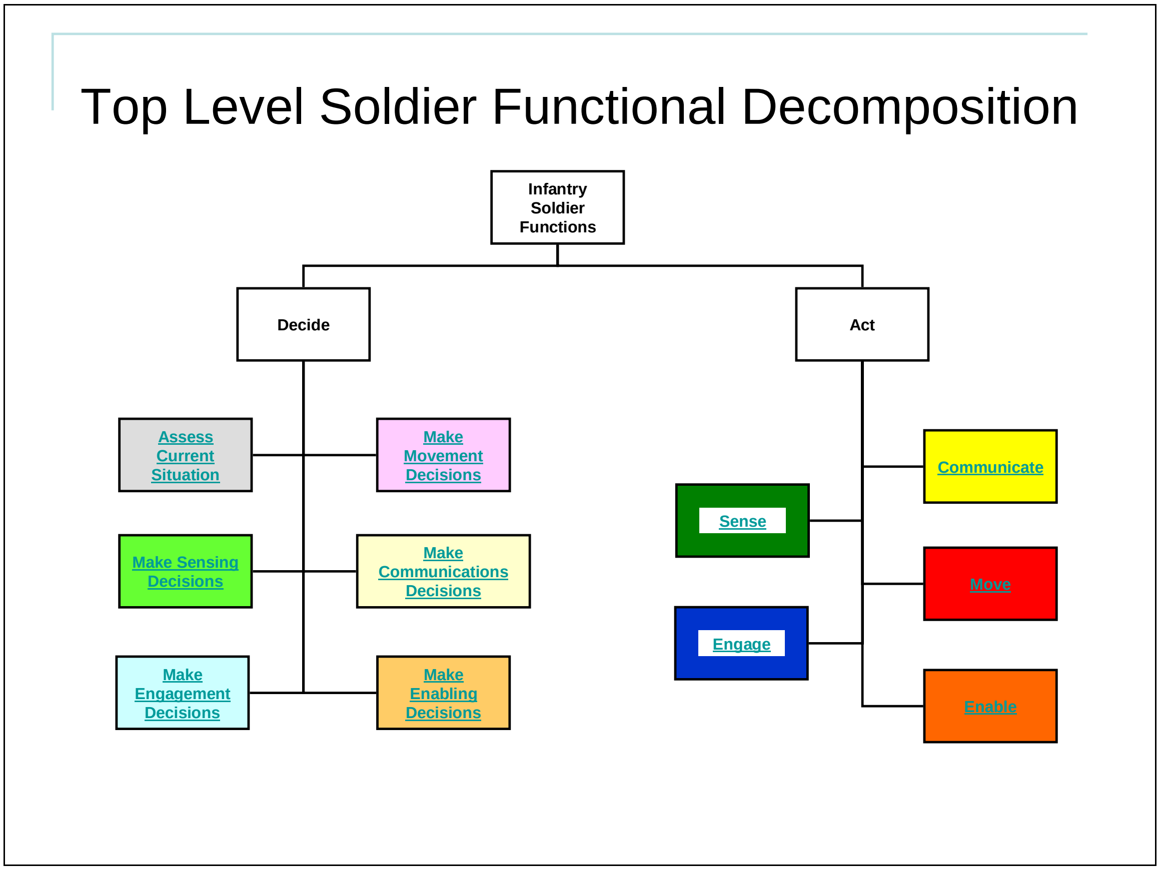

Figure 1 – Top Level Soldier Functional Decomposition from [Tollefson, 2004]

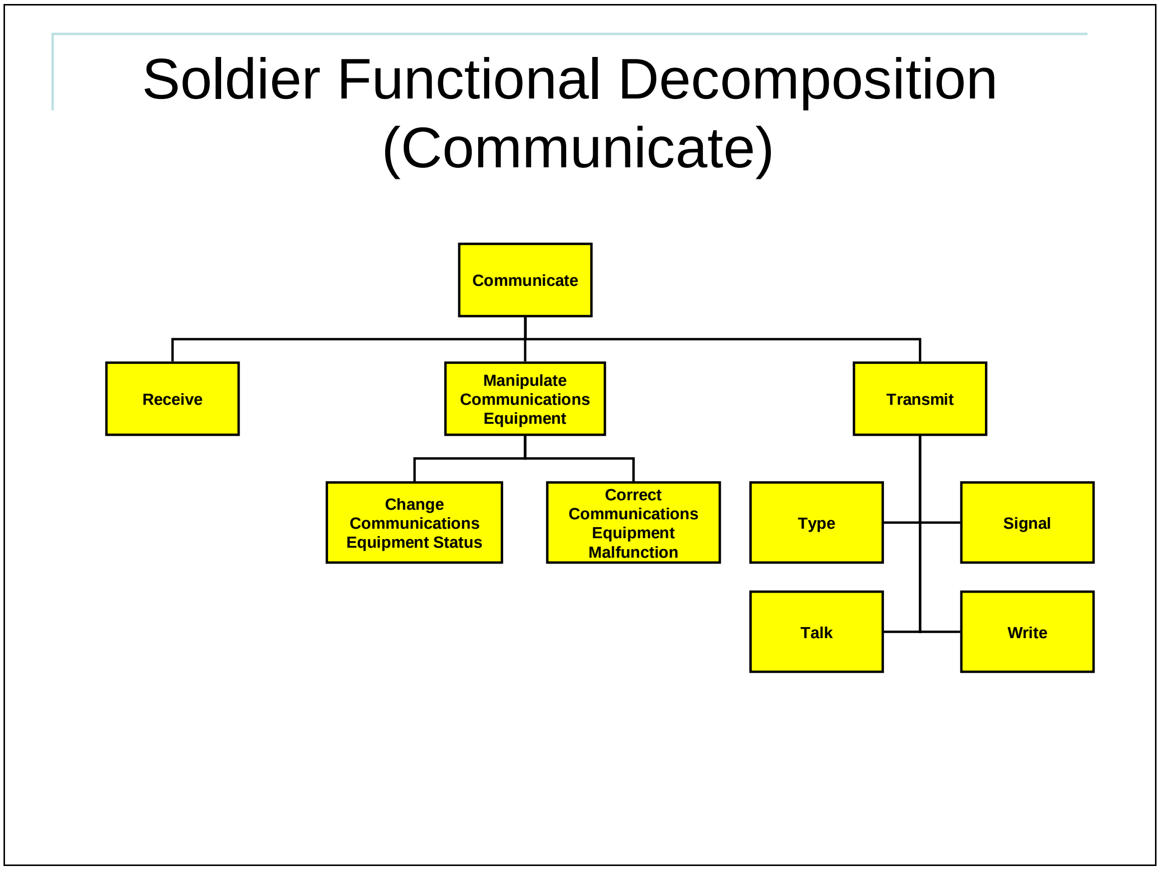

Figure 2 – Soldier Functional Decomposition for Communicate from [Tollefson, 2004]

Chapter 3: Measures of Effectiveness (MOE) and Measures of Performance (MOP) Development Phase

3.1 General

In this phase, metrics are selected to help address the EEAs. The EEAs and the functional decomposition are used as tools to develop the MOEs and the MOP hierarchy. In turn, the MOEs and the MOP hierarchy can be used to refine the EEAs and the functional decomposition. The purpose of the work in this phase is to provide a common set of FFW performance measures so that A&ET results can be integrated and compared. This work also helps to define the data collection requirements for the A&ET events. Important, standard definitions for this work include:

- Measure of Effectiveness (MOEs) – Important output measures that are used to compare the overall effectiveness of alternative small combat unit designs. MOEs measure how well the mission is performed. MOEs are usually scenario-dependent.
  - Example: Number of enemy killed during the mission
- Measures of Performance (MOPs) – Measures that are believed to support MOEs. These measures are used to compare capabilities of small combat unit sub-systems. MOPs may represent a measurement of system behavior. MOPs may also be measurable by a test process.
  - Example: Maximum effective range of a weapon system

- <u>Analysis Factor</u> – An input attribute that is varied at two or more levels in a designed experiment. An analysis factor is fixed for an individual run of the designed experiment. In an experiment that is used to determine the relationship between MOPs and MOEs, an analysis factor may be related to a proposed MOP.
  - Example: Maximum effective range of a weapon system
    - Level 1: 400 meters
    - Level 2: 600 meters
    - MOE in this example: Number of enemy killed during the mission

The result of steps 3 and 4 includes:

- Common, composite MOE variants for A&ET efforts (based on the current MOUT vignette)
- A holistic MOP hierarchy
- A common set of priority MOPs for A&ET efforts

The primary vignette currently under study in the FFW program is a MOUT vignette that was developed during Phase 1 of the program. The MOEs described below address this MOUT vignette. However, other vignettes have been addressed in previous analysis events and the concepts that follow can be generalized and adjusted to meet the needs of other potential vignettes. The first list of primary MOPs are useful for combat scenario analysis events. It is noted that some categories of common performance measures may not be appropriate for some A&ET combat scenario analysis events. In those identified areas, a list of other suggested primary MOPs is provided in a second list for use with other analysis activities.

3.2 *Measures of Effectiveness*

In step 3, MOEs are developed and refined based upon the previous steps, input from the FFW PMT and the FFW SoSEIT, and the vignette under study. The MOEs are developed to compare the overall performance of alternative FFW small combat unit designs. The war-fighting expectations of the FFW program require us to consider multiple performance metrics. The MOEs are identified and then prioritized based on the scenario and the EEAs. Next, we develop a value function based on the prioritization of the individual responses. To do this, we normalize the MOEs to develop a "Desirability Function." See [Schamburg, 2004]. This is done so that the Desirability Function can be related to the tactical mission that is described in the vignette. For this reason, we call the this function the "Mission Response Function." Our MOEs are directly related to the platoon's survivability, lethality, ability to seize and control terrain, and the time to complete the mission. Therefore, in order of importance, the MOEs include:

1. y_1 = (Lethality) the number of enemy casualties,
2. y_2 = (Survivability) the number of friendly casualties,
3. y_3 = (Seizing the Objective) whether or not the small combat unit seized the objective (zero if the small combat unit does not seize the objective and one if the small combat unit seizes the objective), and
4. y_4 = (Mobility) time to complete the mission.

We look at the responses individually, in order of priority, but we also look at a developed Mission Response Function. Given the prioritization of the MOEs, our Mission Response Function is directly related to the tactical mission. The Mission Response Function is given by:

$$MR = \sum_{i=1}^{k} v_i z_i$$

where v_i is the value of the ith normalized response, z_i. The v_i are developed so that $\sum_{i=1}^{k} v_i = 1$ and $0 \le v_i \le 1$ for all v_i. With our mission response function, larger is better. As an example, we normalize the response for lethality in the following way:

$$z_1 = \frac{(y_1 - y_{1\min})}{(y_{1\max} - y_{1\min})} \quad ,$$

where y_1 represents the number of enemy casualties, $y_{1\min}$ represents the minimum number of enemy casualties that could have occurred, $y_{1\max}$ represents the maximum number of enemy casualties that could have occurred, and z_1 represents the resulting normalized value. See [Schamburg, 2004] for more detail on this subject.

Table 1 shows the recommended primary weights and some discrete sensitivity analysis weightings for the current FFW MOUT vignette under study. These weights are subject to input from the FFW PMT and the SoSEIT and any adjustments to the vignette.

Recommended Relative Weights for Composite MOE
(Current MOUT Vignette)

	Primary	Sensitivity Analysis			
	MR 1	MR 2	MR 3	MR 4	MR 5
Lethality	0.3	0.4	0.3	0.25	0.25
Survivability	0.3	0.3	0.4	0.25	0.25
Seizing the Objective	0.3	0.2	0.2	0.4	0.25
Time to Complete Mission	0.1	0.1	0.1	0.1	0.25
	1	1	1	1	1

Table 1 – Recommended Relative Weights for Composite MOE for the Current MOUT Vignette

3.3 Measures of Performance

In step 4, we develop and refine the MOP hierarchy based upon review of the previous steps and consideration of the documents identified in section 1.3. Again, MOPs are measures that we believe will support the MOEs. These measures are used to compare capabilities of small combat unit sub-systems. An MOP may represent a measurement of system behavior and may be measurable by a test process. An important aspect related to MOPs (that often causes difficulties for analysts) is that MOPs must be quantifiable for data collection, comparison, and analysis purposes. The developed broad, top level objectives of the MOP hierarchy are identified in figure 3 below.

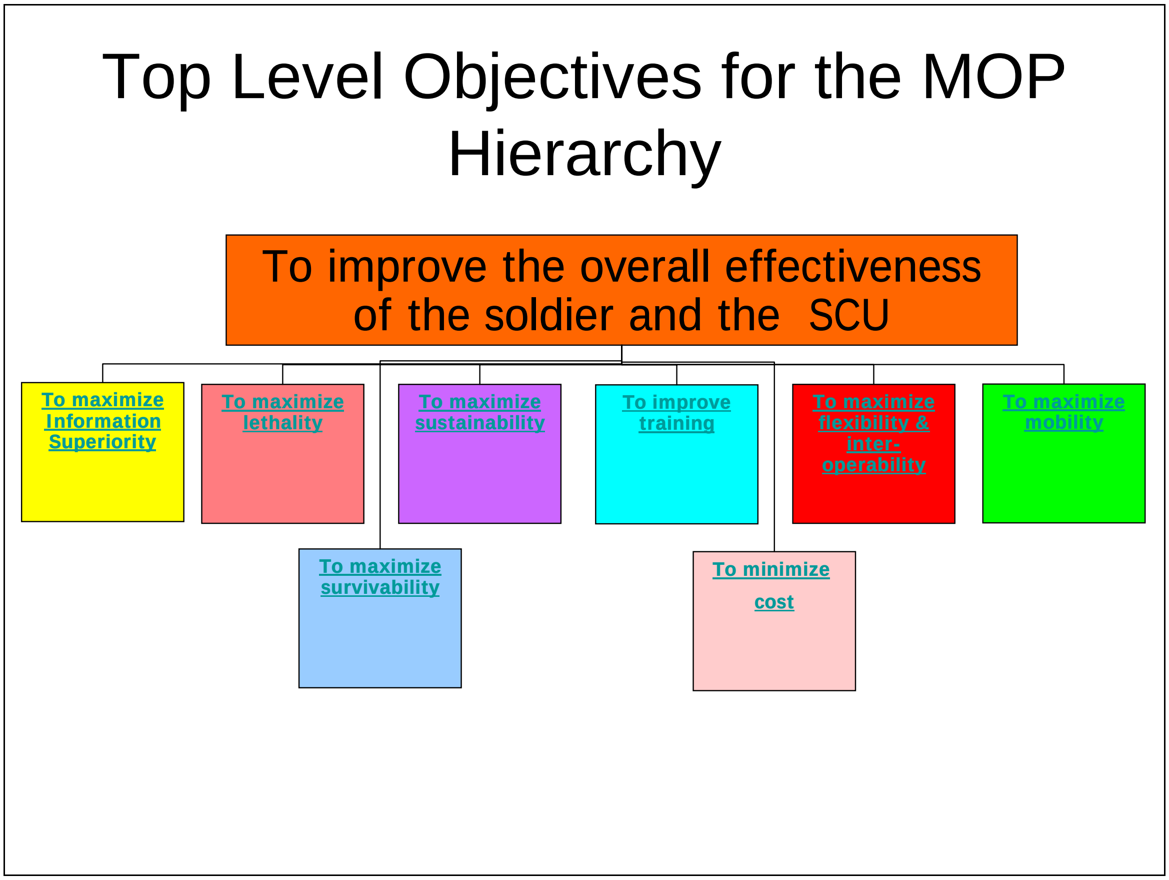

Figure 3 - Top Level Objectives for the MOP Hierarchy

Next, more specific supporting objectives are defined. These lower level objectives support the higher level objectives. The MOPs are defined last. They are at the bottom level of the hierarchy and are even more specific than the supporting objectives.

The development and refinement of the MOP hierarchy included brain-storming sessions through the use of group systems software. While providing input for an improved MOP hierarchy, the group systems work also provided input for a set of common, high-valued MOPs for FFW analysis and experimentation efforts. As an example, some results of the group systems work from a session conducted on 3 March 2005 are provided in Appendix A. Figures 4 through 6 provide examples of the refined

MOP hierarchy for the Information Superiority and Lethality objective areas. The remainder of the refined MOP hierarchy is provided in Appendix B.

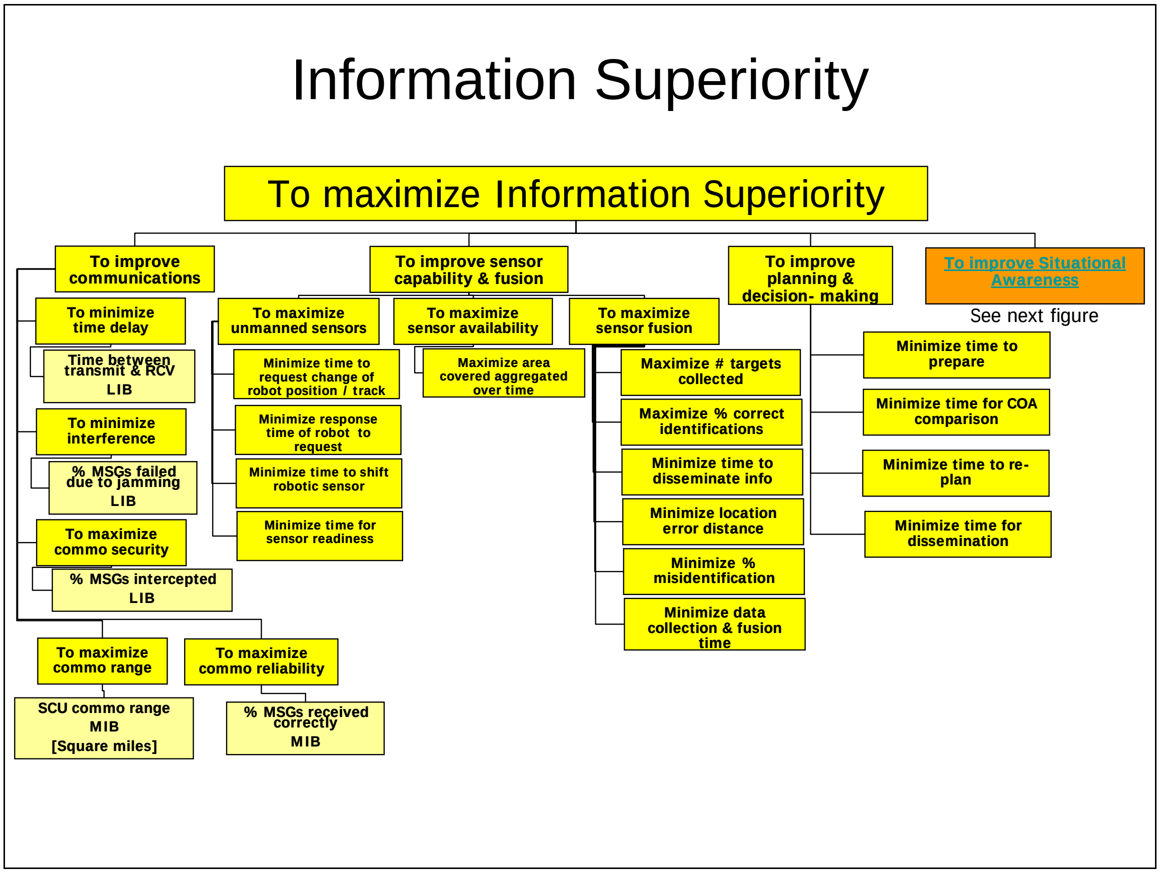

Figure 4 – Information Superiority MOP Hierarchy

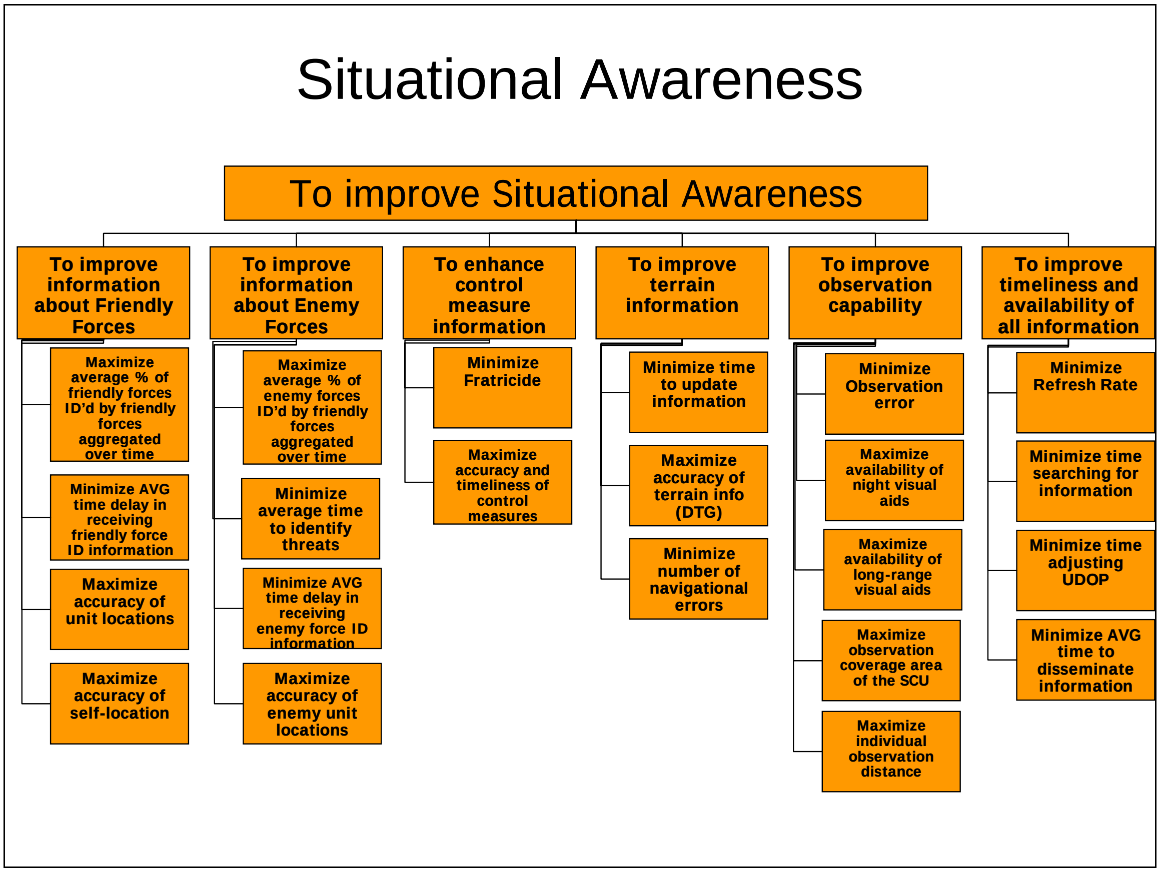

Figure 5 - Situational Awareness MOP Hierarchy Supporting the Information Superiority MOP Hierarchy

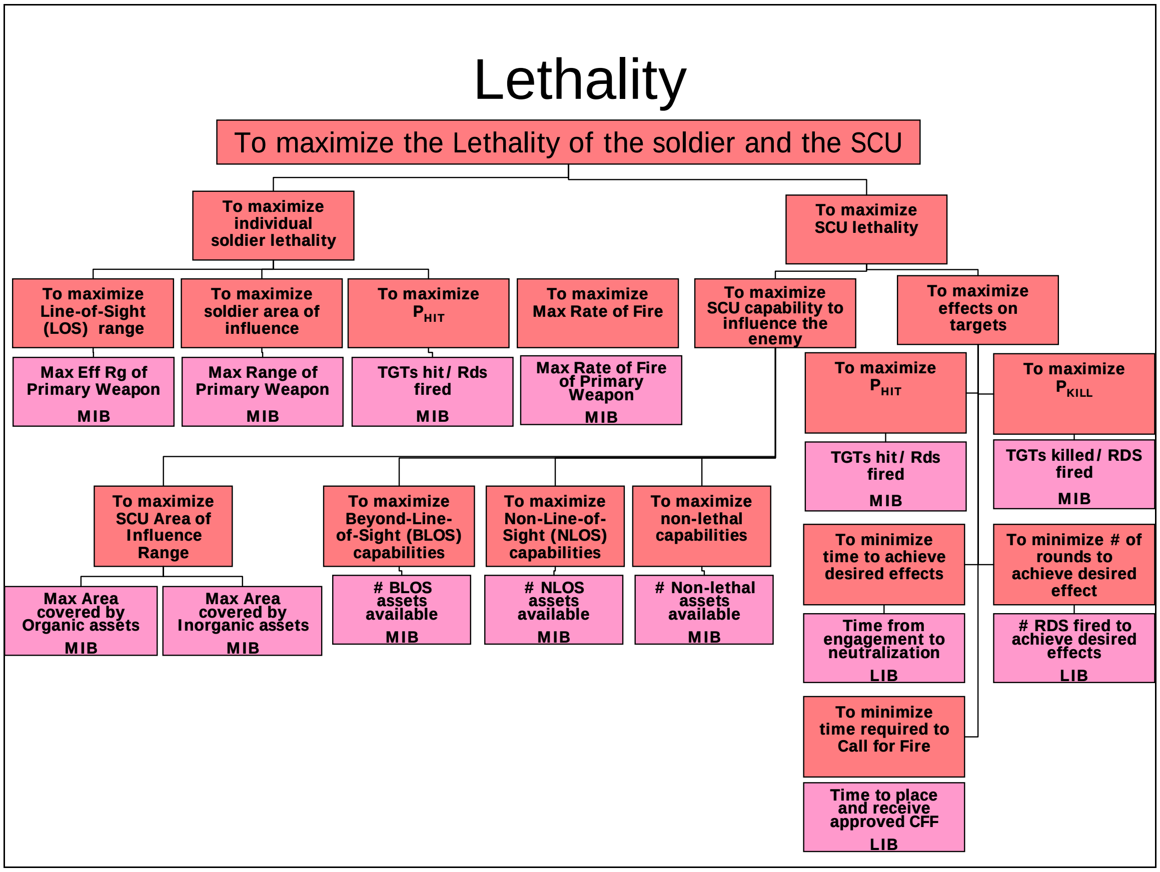

Figure 6 - Lethality MOP Hierarchy

The MOP hierarchy can be used as a tool to help identify and refine the following:

1. The EEAs developed in step 1 of this work.
2. The soldier functions identified in step 2 of this work.
3. FFW operational capabilities and functional capabilities.
4. Potential technologies that have been over-looked.

As part of step 4, important and common MOPs were identified based on assessed importance and their frequency in addressing the EEAs. The desire to stick to the “important, common MOPs” is that the common use of these can make it easier to relate one A&ET event to another and therefore can make it easier to develop broader generalizations about the results of the analyses. Through use of the primary MOPs, A&ET analysis results from different events can be better integrated and compared. For some EEAs or for some A&ET events, the following list may not be appropriate. In those cases, one might refer to the more complete MOP to EEA mapping that is defined as part of step 5. Because of this, step 5 is closely related to this part of step 4. Furthermore, the results of the MOP to EEA mapping of step 5 can be used to refine the list of “important, common MOPs” of step 4. The first list of important, common MOPs includes those which may be assessed as part of combat simulations or combat scenario experimentation. Because of the breadth of the Information Superiority objective area, a table is used to show the resulting, primary MOPs for it. Primary MOPs for the other objective areas are simply listed below table 2.

Primary MOPs that might be addressed with combat simulations or combat scenario experimentation:

Information Superiority
(Primary MOPs)

Information Superiority (Communication)	Information Superiority (Sensors)	Information Superiority (Mission Planning & Rehearsal)	Information Superiority (Situational Awareness & UDOP)
SCU communications range	Area covered by sensors, aggregated over time	Time to prepare plan	Average % of friendly forces ID'd by friendly forces, aggregated over time
Average soldier communications range	% of targets detected, aggregated over time	% of plan completed using FFW capabilities	Average % of enemy forces ID'd by friendly forces, aggregated over time
Average communications time delay	% of targets ID'd, aggregated over time	% of plan distributed and done collaboratively	Average time delay in receiving friendly force ID information
			Fratricide - # of friendly forces killed by friendly forces
			Average time delay in receiving enemy force ID information

Table 2 - Primary MOPs for Information Superiority

Primary MOPs for Lethality

1. Average time to achieve desired effect on desired target
2. % of targets that receive desired effect
3. Area covered by effects w/ organic assets
4. Area covered by effects with inorganic assets available

Primary MOPs for Sustainability

1. Average time that the SCU can operate without re-supply. This is the minimum of any critical supply item sustainment duration.
2. Maximum soldier battery power (energy) required by duty position
3. Average number of rounds, by type, required by duty position

Primary MOPs for Mobility

1. Average soldier fighting load weight
2. Average soldier approach march load weight
3. Average rate of movement of soldiers

Primary MOPs for Survivability

1. # of shots taken at blue
2. % of body covered by ballistic protection
3. Caliber of round to which ballistic protection is effective
4. # of blue detections by red

<u>Measures that are best addressed with methods other than simulation or combat scenario experimentation.</u>

<u>Primary MOPs for Training</u>

1. % of critical individual tasks covered with embedded training capability
2. % of collective tasks covered with embedded training capability
3. Average time required to gain proficiency
4. Average time required to complete a task

<u>Primary MOPs for Flexibility & Interoperability</u>

1. The number of operational scenarios within which the FFW equipped SCU can successfully operate (consider mission and environment)
2. The number of external systems with which the FFW equipped SCU is interoperable
    - for interoperable, consider: communications, power supplies, size, and weight requirements

<u>Primary MOP for Cost</u>

The expected life-cycle cost of the FFW equipped platoon

Chapter 4: Integrated Analysis and Experimentation Framework Development Phase

4.1 General

The next phase of this work involves the development of an integrated analysis and experimentation framework. In step 5, capabilities are mapped to the EEAs to identify modeling requirements associated with the respective EEAs. Also, MOPs are mapped to the EEAs to identify data collection requirements that are associated with the respective EEAs. Based upon step 5, step 6 forms the basis of appropriate A&ET event identification and feasibility associated with the respective EEAs. As a whole, steps 5 and 6 result in the FFW Integrated Analysis and Experimentation Framework. Once FFW design and development questions are raised, EEAs can be identified to address the respective questions. With selected EEAs identified, this framework can then be used as a tool to define A&ET events by identifying:

1. The necessary capabilities for developing the event
2. The necessary MOPs for assessing the event
3. The appropriate analysis or experimentation activity

4.2 Capability and MOP Mapping to EEAs

Step 5 includes the mapping of capabilities to the EEAs. This process requires review of the wording of the EEAs to determine which capabilities are required in order to address the EEAs. Similar to the EEA groupings and the top level objectives in the MOP hierarchy, the FFW capabilities groupings include:

- Situational Awareness
- Sensor Fusion
- Communications
- Information Management
- Battle Management and Command & Control
- Netted Effects
- Survivability
- Sustainability
- Training
- Interoperability

This step also includes the mapping of MOPs to the EEAs. Similar to the mapping of capabilities to EEAs, mapping the MOPs to the EEAs requires review of the wording of the EEAs to determine which MOPs are required to assess the EEAs. The entire list of MOPs that was presented in section 3.3 and Appendix B was considered in this work. However, an effort was made to use the primary MOPs when appropriate.

Tables 3 and 4 show examples of the results of this work. The entire results of this step are contained in the file, "EEA Capability and MOP Mapping v2.0 (2 June 05).xls" and this file is now maintained by the FFW A&ET. This file is the first half of the Integrated Analysis and Experimentation Framework.

Proposed Additional EEAs	EEA Sub- Questions	Primary MOPs	Operational Capability	Functional Capability
1.16 What is the best way to distribute situational awareness capabilities throughout the SCU?				
	1.16.1 Within the SCU, what is the best distribution of the different modes of presenting situational awareness information?	Average time searching for information	SA_UDOP	Self Location
				Reporting self location
				Blue location
				Blue location Systems and Equipment
				Threat Location in AO
				Alerts
				See Control Measures
		% of time adjusting UDOP		
		% of time responding to UDOP		
		% correct in distinguishing one entity from another		
		Fratricide = # of friendly forces killed by friendly forces		

Table 3 – Capability and MOPs Mapping to Example Information Superiority EEAs (part 1)

Proposed Additional EEAs	EEA Sub- Questions	Primary MOPs	Operational Capability	Functional Capability

1.16 What is the best way to distribute situational awareness capabilities throughout the SCU?				
	1.16.2 What situational awareness time delays are appropriate?	Fratricide = # of friendly forces killed by friendly forces	Communication	Receive Sensor Feeds
				Nets
				Internal Higher External/Joint Nets
		Time to achieve desired effect on desired target	SA_UDOP	Self Location
				Reporting self location
				Blue location
				Blue location Systems and Equipment
				Threat Location in AO
				Alerts
				See Control Measures
		% of targets that receive desired effect	Information Management	Application -BC
				Application -MP&R
				Application -SA
				Application -Sustainment
		# of blue detections by red	Sensor Fusion	Emplace Sensors
				Sensor Fusion Level 0:
				Sensor Fusion Level 1
				Sensor Fusion Level 2
				Update SA, BDA & map features
		Time required to clear objective	Netted Effects	Acquire Targets
				Enter Tgt Info SCU Network

Table 4 - Capability and MOPs Mapping to Example Information Superiority EEAs (part 2)

4.3 A&ET Event Feasibility for Addressing EEAs and Mapping A&ET Tools to EEAs

Step 6 includes an assessment of the feasibility in addressing the EEAs with analysis or experimentation events. It also includes suggested best suited analysis tools for addressing each EEA. This work requires an understanding of the analysis, modeling, simulation, and experimentation tools, capabilities, and limitations. The A&ET includes Subject Mater Experts (SME) with this understanding. This work also requires consideration of the capabilities and MOPs that are mapped to each EEA as described in the previous section. The Analysis Team conducted the first part of this work with a focus on analysis tools short of live experimentation. The Experimentation Team conducted the second part of this work with a focus on laboratory, live experimentation, and demonstration events. For the feasibility in conducting analysis events, table 5 shows the assessment categories that were used for each EEA:

Modeling and Simulation (Analysis tools, Closed loop, Soldier in the loop, and Virtual Simulations)	
(green)	Green EEAs are more easily addressed in simulations than yellow EEAs.
(yellow)	Yellow EEAs can be addressed in simulations.
(pink)	Pink EEAs are less appropriate for simulation analysis.
(gray)	Gray EEAs are redundant and are color coded (green, yellow, or pink) in the appropriate area.

Table 5 – Analysis Modeling and Simulation Feasibility

For the feasibility in conducting laboratory, live experimentation, and demonstration events, table 6 shows the assessment categories that were used for each EEA:

Demos, Labs, & Live Experimentation	
Y	This EEA can be addressed with live experimentation during Spiral 2
Y/R	This EEA can be addressed with live experimentation, but the scope will be reduced during Spiral 2
N	This EEA cannot be addressed with live experimentation during Spiral 2
	This EEA is not applicable during Spiral 2

Table 6 – Demos, Labs, and Live Experimentation Feasibility

For mapping best suited analysis tools to each EEA, the Analysis Team considered 9 different types of tools. The following paragraphs provide a list of tools with descriptions.

Analysis and Simulation Types and Descriptions

- SS - Spreadsheet Model: This category includes a broad range of possible spreadsheet models.

- Commo - Communications Network Modeling: This category includes a broad range of possible communication models.

- ABM - Agent-Based Model: The agent-based models category includes a broad category of flexible, closed-loop models and simulations. Agent-based models and simulations are exploratory analysis tools. There are several flexible, easy to use combat agent-based simulations readily available. In the agent-based simulation, agents interact and behave autonomously and therefore, the agents do not have to have scripted routes. In these models, agents have the ability to sense their environment, to make decisions, and to interact with other agents. "Humans in the loop" and scripted routes are not required and each simulation run can be completed faster. In turn, this generally allows the ability to explore more variables and to collect more data in a shorter period of time.

- SUTES - Small Unit Team Exploratory Simulation: SUTES is a closed (not SITL), fast running, infantry oriented, architecture simulation developed to address broad FFW questions. Technology use is part of the integrated analyses approach and is the first step in analyzing capabilities to “neck” down SoS choices for higher fidelity simulations such as Joint Conflict and Tactical Simulation (JCATS), OOS, and the IWARS, as well as field experiments.

- JCATS - Joint Conflict and Tactical Simulation: The Joint Conflict and Tactical Simulation (JCATS) is a multi-sided, interactive, high resolution, entity level, joint conflict simulation. It provides multi-service interoperability with ground, air, and water functions. It can be used for SITL as well as closed loop simulations. JCATS capabilities include the ability to conduct activities from tactical up through the Joint Task Force level and across the entire spectrum of conflict. JCATS can be used as a tool for supporting training, analyses, experimentation, mission planning and rehearsal activities. JCATS includes capability to detail the modeling of small group activities in open and urban terrain to include multi-floor buildings with doors, windows, interior walls, replicating day/night operations under differing visibility and lighting conditions to include artificial lighting.

- OOS - Objective OneSAF: OOS is a composable, next generation Computer Generated Force that can represent a full range of operations, systems, and control processes from entity up to brigade level, with variable level of fidelity that supports multiple Army Modeling and Simulation domain applications. OOS is a stochastic, closed as well as SITL, discreet event, 25 plus sided model. OOS is eventually supposed to replace the Brigade/Battalion Battle Simulation (BBS), OneSAF Testbed Baseline (OTB), Janus, Aviation Combined Arms Tactical Trainer (AVCATT)/Close Combat Tactical Trainer (CCTT) SAFs, and JCATS MOUT (Military Operations in Urban Terrain). OOS supports Advance Concepts and Requirements (ACR), Research, Development, and Acquisition (RDA), and Training, Exercises, and Military Operations (TEMO).

- IWARS - Infantry Warrior Simulation: IWARS is a primarily closed-loop (but capable of SITL operation), time-sequenced with event interruptions, stochastic model currently being developed to replace both the Natick Soldier Center's Integrated Unit Simulation System (IUSS) and AMSAA's Infantry MOUT Simulation (AIMS). It will resolve down to the individual soldier. IWARS is being designed to focus on dismounted individuals, small units, and their equipment for assessing operational effectiveness across spectrum of missions, environments, and threats. IWARS concentrates on soldier equipment, behaviors, algorithms, and data. IWARS efforts include addressing current soldier-centric M&S voids that impact the Army's ability to perform ACR and RDA analyses (e.g., Land Warrior AoA, Future

Force Warrior technology trades). IWARS development is heavily influenced by the analysis needs of LW and FFW programs.

- Virtual - Virtual Simulation: Virtual simulations contain a mix of live elements and computer-generated processes. Similar to the SITL category, virtual simulations attempt to more fully immerse the soldiers into the simulation. Soldiers participating in the simulation may be provided with prototype or actual components and subsystems.

- SITL - Soldier in the Loop: This category includes a broad range of possible models in which soldiers take part in the simulation by making various decisions for entities in the simulation.

Using the feasibility assessment categories given in tables 5 and 6 and considering the above listed analysis tools, table 7 shows an example of the EEA feasibility assessments and the best suited A&ET analysis event tools mapped to selected EEAs. The entire results of this step are contained in the file, "EEA MS EXP Feasibility Scrub v2.5 (1 June 05).xls." This file is now also maintained by the FFW A&ET. This file makes ups the second half of the Integrated Analysis and Experimentation Framework.

Proposed EEA	M & S	Best Suited Simulation	Other Possible Simulations	Lab Event	Field Exp	Field Demo
7.1. Will the FFW system provide the ability to more effectively and efficiently complete the spectrum of missions in any environment?	**Green - EEA More Easily Addressed w/ M&S Than Yellow**	IWARS	OOS, JCATS, SUTES, ABM	**N**	**Y**	**Y**
7.2. Will the FFW system provide the ability to more effectively and efficiently complete the spectrum of individual Soldier tasks in any environment?	**Pink - EEA is Less Appropriate for M&S**		IWARS, ABM	**N**	**Y**	**Y**
7.3. Will the FFW system provide the ability to more effectively and efficiently complete the spectrum of SCU collective tasks in any environment?		IWARS	ABM, OOS, JCATS, SUTES	**N**	**Y**	**Y**
8.1. What TTP's should be used by the FFW SCU?		ABM	OOS, SUTES, IWARS, JCATS, Virtual, SITL	**N**	**Y**	**Y**
8.2. What impact do proposed FFW TTPs have on SCU operational performance?		ABM	OOS, SUTES, IWARS, JCATS, Virtual, SITL	**N**	**Y**	**Y**

Table 7 - EEA feasibility assessments and the best suited A&ET analysis event tools mapped to selected EEAs

Chapter 5: A&ET Plan Development Phase

5.1 General

The final phase, the Plan Development phase, of this process includes step 7, the A&ET event planning step. The general approach to this phase is to structure a series of A&ET events so that an integrated, holistic approach can be developed. In order, the A&ET considers the following major analysis events: exploratory simulations, constructive closed-loop simulations, SITL simulations, virtual simulations, and live experimentation events.

Exploratory simulations such as ABM or SUTES offer the ability to look at several EEAs and several analysis factors simultaneously. Without humans-in-the-loop, thousands of experiments can be conducted each day. This offers the ability to investigate a broad range of EEAs and factors. For example, exploratory simulations may offer the ability to look at 20 or more factors in one experimental design. Soldiers are not required in the experimental runs. Although these exploratory simulations do not offer the same high resolution experimentation as those with SITL, they allow us to gain insights that will help guide the experimental designs of the higher resolution simulations.

In order, constructive closed-loop simulations, SITL simulations, virtual simulations, and live experimentation usually allow increased resolution. However, in the same order, they are progressively more time consuming than the exploratory simulations. In general, live experimentation, for example, offers the greatest resolution but is probably the most expensive in terms of costs, human resources, setup times, and experiment run times. Live experimentation may offer the ability to look at only 5 factors in an experimental design. Furthermore, the complete experimental design may take up to a week to complete and would involve more people. A platoon level experiment, for example, would involve around 40 soldiers. See [Schamburg, 2004].

Considering the number of EEAs that can be addressed by the various approaches and the cost of the various approaches, we plan the A&ET events so that exploratory simulations are used in the beginning in order to look at a broad range of issues. The exploratory simulations allow us to identify the more important EEAs and factors and to address them in higher resolution simulations later in the process. We then consider closed-loop constructive simulations, SITL simulations, and virtual simulations. In order, these simulations allow us to look at slightly fewer EEAs but with increased resolution. These events help us to narrow the focus toward the important EEAs and factors even further. Additionally, they offer capabilities that are different than the exploratory simulations and may allow us to look at different EEAs. Finally, we consider live experimentation. Live experimentation provides even greater resolution on the most important EEAs and factors. It may also provide us with the ability to look at EEAs that can not be addressed by using the other methods. Furthermore, live experimentation provides us the opportunity to get feedback from soldiers through questionnaires and interviews. As described before, the planning process for these events requires input from the other FFW teams and the documents listed in section 1.3. In turn, execution of this analysis and experimentation process is used to provide feedback to the other FFW teams and the documents it supports. Figure 7 shows the general iterative nature of the A&ET activities. The sequence described in this paragraph and shown in figure 7 is iterative and flexible. As the FFW design and development decision issues shift and as knowledge is gained, the sequence can be adjusted appropriately to support the needs. See [Schamburg, 2004]

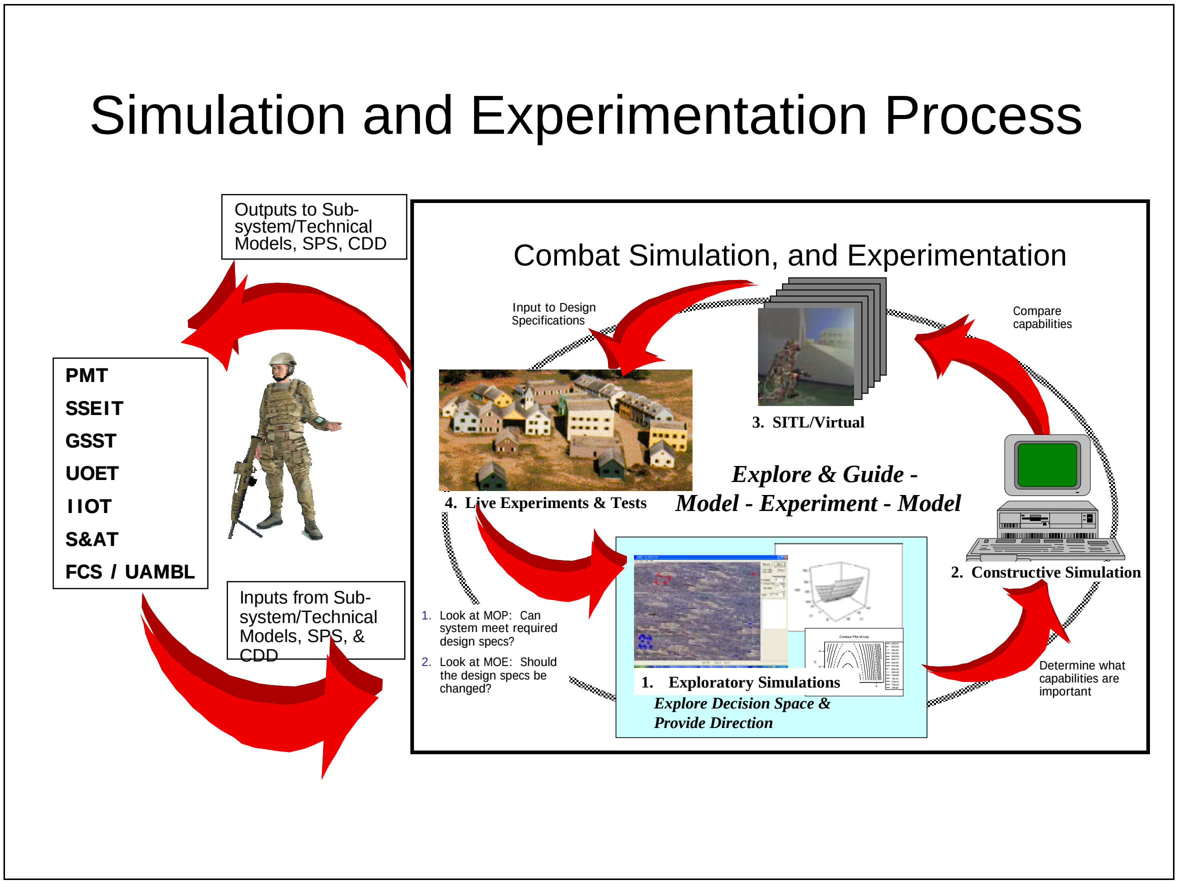

Figure 7 – Simulation and Experimentation Process, [Schamburg, 2004]

5.2 A&ET Event Planning

This step considers the process described in section 5.1 and starts by prioritizing and selecting EEAs based on current FFW design and development decision issues. Prioritizing and selecting EEAs requires input from the FFW PMT and FFW SoSEIT. Next, the A&ET uses the Integrated Analysis and Experimentation Framework ("EEA

MS EXP Feasibility Scrub v2.5 (1 June 05).xls" that was described in section 4.3) to identify appropriate modeling, simulation, or experimentation approach(es). Finally, we use the Integrated Analysis and Experimentation Framework ("EEA Capability and MOP Mapping v2.0 (2 June 05).xls" that was described in section 4.2) to identify capabilities for modeling requirements and candidate MOPs required for data collection and analysis.

5.3 The Initial A&ET Event Plan Developed for Phase 2

As an example, the following describes the initial A&ET event plan that was developed for Phase 2 of the FFW program. This plan is intended to help provide input to design decision issues prior to a live experiment and the FFW Build and Test Phase. The plan is still subject to further prioritization of the EEAs, additional input form the FFW PMT and the FFW SoSEIT, and review of simulation development and completion schedules. Starting with the general concept, this plan has 5 parts.

1. General Concept: Given the time available for FFW Phase 2 and based on the discussion in sections 5.1 and 5.2, the following provides the general concept for the Phase 2 A&ET Event Plan:
    - As a minimum, conduct 3 simulation events that build on each other in order to provide analysis results that will improve FFW program decision making leading to the live experiment and the Build & Test phase.
    - In sequence, these events provide increased focus on important FFW decision factors and progressively higher resolution simulation and analysis techniques.

- As the events progress, there will be flexibility to shift the focus of subsequent events in order to address shifts in program decision making issues.
- Simulation events during the Build & Test phase will focus more on distributed capability and TTP issues.

2. Schedule: Figure 8 shows the proposed schedule for the events.

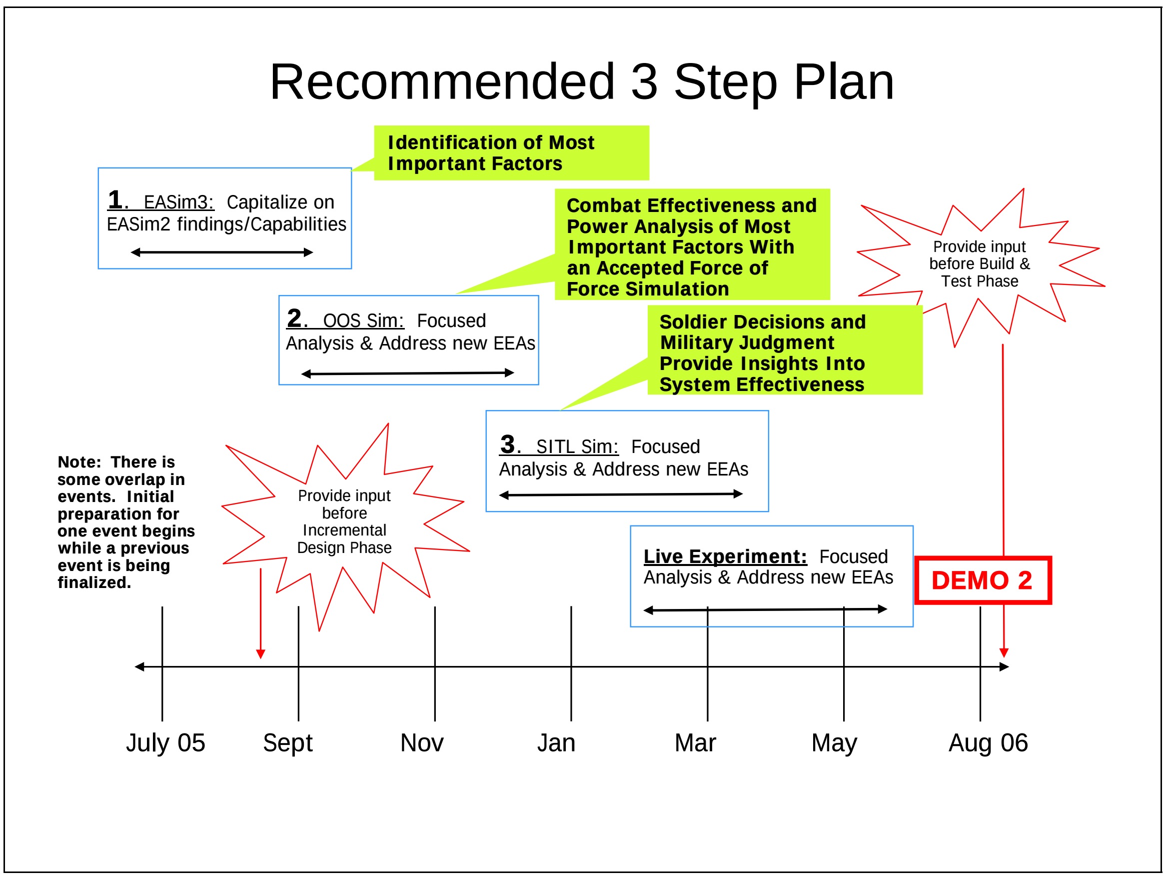

Figure 8 – A&ET Event Plan Schedule

3. Event 1: Figure 9 provides the general description of event 1, the exploratory simulation.

Event 1: Exploratory Simulation

- Purpose:
  - Provide input to important FFW decisions for FFW Incremental Design Phase
- Initial proposed EEAs and Identified Capabilities:
  - COP precision and latency requirements. EEAs include 1.4.3 (target location accuracy), 1.4.7.4 (friendly location accuracy), 1.4.7.5 (friendly location update rate), and 1.16.2 (COP update delays).
  - Sensor-to-shooter timeline requirements. EEAs include 1.4.2 (sensors/platforms to support sensor-to-shooter timelines), 1.4.3 (target location accuracy), 1.17 (UAV contribution), 2.4.1 (weapons/fire control mix), and 2.4.3.1 (range of sensor-to-shooter timelines).
- Alternate EEAs and Identified Capabilities:
  - Netted Effects. Determine how to distribute sensor, communications, and fire control capabilities across the SCU.
- Simulation Tool:
  - Recommended: SUTES
  - Alternate: ABM
- Military Context:
  - Recommended: MOUT
  - Alternate: SASO
- Primary MOEs:
  - Lethality
  - Survivability
  - Seizing the Objective
  - Time to complete Mission
- Primary MOPs:
  - Average time to achieve desired effect on desired target
  - % of targets that receive desired effect
  - Area covered by effects w/ organic assets
  - Area covered by effects with inorganic assets available
  - Fratricide
  - Average rate of movement of soldiers
- Schedule:
  - Initial Prep - July and Aug
  - Simulation execution in Sept

Figure 9 - General Description of event 1, the Exploratory Simulation

4. Event 2: Figure 10 provides the general description of event 2, the closed-loop constructive simulation.

Event 2: Closed-Loop Constructive Simulation

- Purpose:
  - Provide input to important FFW decisions as part of the FFW Incremental Design Phase
- Initial proposed EEAs and Identified Capabilities:
  - Power Usage Profiles. 3.8.7 (overall leader and Soldier energy requirements), 3.8.1 (UDOP power requirements), 3.8.2 (netted effects power requirements), 3.8.3 (weapons distribution power implications), 3.8.5 (sensors distribution power implications), and 3.8.10.1 (distribution of communications effects on 24-hour autonomous operations).
- Alternate EEAs and Identified Capabilities:
  - Netted Effects. Determine how to distribute sensor, communications, and fire control capabilities across the SCU. 1.4.1 and 1.4.2 (distribution of sensors support of netted effects), 1.4.4 (distribution of comms), 1.8.4 (reduced exposure firing), 1.7 (mix of sensors for target detection), 1.16.1 and 1.16.2 (situational awareness delays and refresh rates), 2.4.1 (fire control), 2.4.9.1 (comms distribution effect on netted effects), 2.4.10.1 (distribution of helmet-mounted fused sensors).
- Simulation Tool:
  - Recommended: OOS (if ready prior to Sept 05)
  - Alternate: IWARS
- Military Context:
  - Recommended: MOUT
  - Alternate: SASO
- Primary MOEs:
  - Lethality
  - Survivability
  - Seizing the Objective
  - Time to complete Mission
- Primary MOPs:
  - Average time that the SCU can operate without re-supply.
  - Maximum soldier battery power (energy) required by duty position
  - % of targets that receive desired effect
  - Average soldier fighting load weight
  - Average soldier approach march load weight
- Schedule:
  - Initial Prep – Sept and Oct
  - Simulation execution in November and Early December

Figure 10 - General Description of Event 2, the Closed-loop Constructive Simulation

5. Event 3: Figure 11 provides the general description of event 3, the SITL simulation.

Event 3: SITL Simulation

- Purpose:
  - Provide input to important FFW decisions prior to the FFW Build & Test Phase
- Initial proposed EEAs and Identified Capabilities:
  - COP precision and latency requirements. EEAs include 1.4.3 (target location accuracy), 1.4.7.4 (friendly location accuracy), 1.4.7.5 (friendly location update rate), and 1.16.2 (COP update delays).
  - Fratricide avoidance using Blue-Force Tracking. EEAs include,1.4.7.4 (position accuracy), and 1.4.7.5 (COP update rate).
- Alternate EEAs and Identified Capabilities:
  - TTPs that provide the best performance of battle drills in an FFW SCU
- Simulation Tool:
  - Recommended: SITL (w/ OOS if used for event 2. Otherwise, use JCATS)
  - Alternate: Virtual
- Military Context:
  - Requires 10 to 15 soldiers
  - Recommended: MOUT
  - Alternate: SASO
- Primary MOEs:
  - Lethality
  - Survivability
  - Seizing the Objective
  - Time to complete Mission
- Primary MOPs:
  - Average time to achieve desired effect on desired target
  - % of targets that receive desired effect
  - Area covered by effects w/ organic assets
  - Area covered by effects with inorganic assets available
  - Fratricide
  - Average rate of movement of soldiers
- Schedule:
  - Initial Prep – Nov / Dec 05
  - Simulation execution in Mar 06

Figure 11 - General Description of Event 3, the SITL Simulation

Chapter 6: Summary and Conclusions

In summary, some key contributions from this work include:

1. **<u>A Refined Set of EEAs</u>:** As described in section 2.2 two additional categories of EEAs ("Flexibility & Interoperability" and "Tactics, Techniques, & Procedures") were added and additional EEAs were proposed in other categories to provide a more complete list of issues that should be considered for FFW analysis and experimentation. Furthermore, this process resulted in recommended restructuring of existing EEAs to align them more with the categories their respective categories and to make them more focused so that they can be better addressed with A&ET events.

2. **<u>MOP Hierarchy</u>**: As described in section 3.3, The MOP hierarchy can be used as a tool to help identify and refine the following:
   a. The EEAs developed in step 1 of this work.
   b. The soldier functions identified in step 2 of this work.
   c. FFW operational capabilities and functional capabilities.
   d. Potential technologies that have been over-looked.

3. **<u>Lists of Primary MOEs & MOPs and a Composite MOE</u>**: As described in sections 3.1, 3.2, and 3.3, the composite MOE (the Mission Response Function) and these lists provide a common set of FFW performance measures so that A&ET results can be integrated and compared. Use of these performance measures will make it easier to relate one A&ET event to another and therefore can make it easier to develop broader generalizations

about the results of the analyses. This work also helps to define the data collection requirements for the A&ET events.

4. **<u>An Integrated Analysis and Experimentation Framework</u>:** As described in section 4.1, this framework can then be used as a tool to plan and define A&ET events. It helps to identify and select:

    a. The necessary capabilities for modeling a simulation event or for developing a live experiment

    b. The necessary MOPs for data collection and assessing the event

    c. The appropriate analysis or experimentation activity

5. **<u>An Initial A&ET Event Plan for FFW Phase 2</u>:** Section 5.3 provides an initial A&ET Event Plan for Phase 2 of the FFW program. This general plan can be used to improve FFW design and development decision making and can serve as an example for the development of future A&ET Event Plans.

6. **<u>A Methodology for Developing an Integrated Analysis Framework and Analysis & Experimentation Event Plans</u>:** As outlined in section 1.2, overall, this work provides a methodology for developing an integrated framework and analysis & experimentation event plans. The four phase general methodology can be used for other future S&T or acquisition programs. The general process described in section 5.1 and 5.2 provides the final tasks required to develop analysis and experimentation plans.

The steps outlined in this work are intended to be iterative and flexible. For example, a refinement in the MOP hierarchy may give rise to a refinement in the EEAs. Furthermore, the list of EEAs, the functional decomposition, the MOP hierarchy, and the developed Integrated Analysis and Experimentation Framework may be used as tools for other A&ET analysis activities and planning and other FFW program activities. Each of the above steps in this work requires careful consideration of the documents listed in section 1.3. In turn, the analysis results should be used as input to these documents. Furthermore, the development of the A&ET event plans requires input from other FFW teams (esp. the FFW PMT and the FFW SoSEIT). With appropriate input from those teams, the output of the A&ET efforts will provide great value to the FFW program.

In an effort to improve the Integrated Analysis and Experimentation Framework and the A&ET Event Plan, future work related to this effort should involve increased A&ET communication and coordination with the FFW PMT, the FFW SoSEIT, and the other FFW teams. In turn, this coordination should be used to update the tools and the plans developed in this effort. This report and the related documents are intended to be "living documents." They should be refined and improved as FFW design and development decision requirements shift and as knowledge is gained through the execution of A&ET events.

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List of Acronyms

AAR	After Action Review
A&ET	Analysis and Experimentation Team
AiTD	Aided Target Detection
ATD	Advanced Technology Demonstration
BLOS	Beyond Line of Sight
BMT	Business Management Team
C2V	Command and Control Vehicle (FCS)
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CAB	Combined Arms Battalion
CAS	Close Air Support
CBA	Cost Benefit Analysis
CBT21	Combat XXI
CDD	Capability Development Document
CDE	Critical Design Event
CDP	Capstone Demonstration Plan
CEP	Circular Error Probable
COP	Common Operational Picture
DCD	Directorate of Combat Development
DVO	Direct View Optics
EA	Exploratory Analysis
EEA	Essential Elements of Analysis
EED	Engineering Evaluation & Demonstration
EEP	Engineering Evaluation Plan
EIPT	Executive Integrated Product Team
ESS	Embedded Soldier Software
EUE	Early User Experiments
EXFOR	Experimental Force
FCS	Future Combat System
FFW	Future Force Warrior
FRAGO	Fragment Order
FRAV	Fratricide Avoidance
GDC4S	General Dynamics C4 Systems
GPS	Global Positioning System
GUI	Graphical User Interface
HMFS	Helmet-Mounted Fused Sensors
IA	Integrated Analysis
IAP	Integrated Analysis Plan
IAS	Integrated Analysis & Simulation
IAWG	Integrated Analysis Working Group
ICV	Infantry Carrier Vehicle
IER	Information Exchange Requirements

IFFN	Identify Friend, Foe or Neutral
IMN	Information Mgmt & Networking
IMT	Individual Movement Technique
IPR	In Process Review
IPT	Integrated Product Team
ISS	Individual Soldier Sensor
IWARS	Infantry Warrior Simulation
JCATS	Joint Conflict and Tactical Simulation
KPP	Key Performance Parameters
LAM	Loitering Attack Munitions/Missile
LOE	Limited Objective Experiments
LOS	Line of Sight
LSI	Lead System Integrator
LTI	Lead Technology Integrator
LW	Land Warrior
LW-SI	Land Warrior–Stryker Interoperable
M&S	Modeling and Simulation
MANPRINT	Manpower & Personnel Integration
MAPEX	Map Exercise
MOE	Measure of Effectiveness
MOP	Measure of Performance
MOUT	Military Operations on Urban Terrain
MUGS	Man-packable Unmanned Ground System
MULES	Multi-function/Utility Logistics Vehicle
NAI	Named Area of Interest
NCO	Noncommissioned Officer
NE	Netted Effects
NLOS	Non Line-of-Sight
NLT	Not Later Than
NS	Netted Sensors
OCSW	Objective Crew Served Weapon
OFW	Objective Force Warrior (Earlier name for FFW)
OICW	Objective Individual Combat Weapon
OOS	Objective OneSAF system
OPNET	Operational Networking
OTB	Objective One SAF Test Bed
P&A	Producibility & Affordability Team
P&E	Power & Energy
PAM	Precision Attack Munitions/Missile
PEO	Program Executive Office
PL	Platoon Leader
PMT	Program Management Team
PSG	Platoon Sergeant
RNCO	Robotics Non-Commissioned Officer
S&T	Science and Technology
SA	Situational Awareness

SAF	Semi-Automated Forces
SBL	Soldier Battle Lab
SBS	Soldier-Borne System
SCU	Small Combat Unit
SEPT	System Engineering Process Team
SET	System Engineering Team
SIL	System Integration Lab
SIT	Software Integration Team
SITL	Soldier In the Loop
SL	Squad Leader
SME	Subject Matter Expert
SOO	Statement of Objectives
SoS	System of Systems
SoSEIT	System of Systems Engineering Integration Team
SoSUE	System of Systems User Experiment
SPIES	Soldier Protection & Individual Equipment Systems
SPS	System of Systems Performance Specification
SSE	Squad Synthetic Environment
SUGV	Small Unmanned Ground Vehicle
SUTES	Small Unit Team Exploratory Simulation
TPO	Technology Program Office
TRADOC	U.S. Army Training and Doctrine Command
TSM	TRADOC Systems Manager
TTP	Tactics, Techniques and Procedures
UA	Unit of Action
UAV	Unmanned Aerial Vehicle
UDOP	User Defined Operational Picture
UE	User Experiment
UGV	Unmanned Ground Vehicle
UOET	User & Operational Effectiveness Team

Appendix A: Example Group Systems Work for Improvement of the FFW MOP Hierarchy

FFW Group Systems MOP Report

The following document provides the results of the Integrated Analysis and Experimentation group systems work that was performed on 3 March 2005. The input from this work was used to develop an improved MOP Value Hierarchy and an improved set of common, high-valued MOP for FFW Analysis and Experimentation efforts. This resulted in 2 ppt files: "FFW Value hierarchy 09 March 05.ppt" and "FFW MOE MOP 09 March 05.ppt."

I. MOP Hierarchy Improvement Recommendations

1. Sustainability

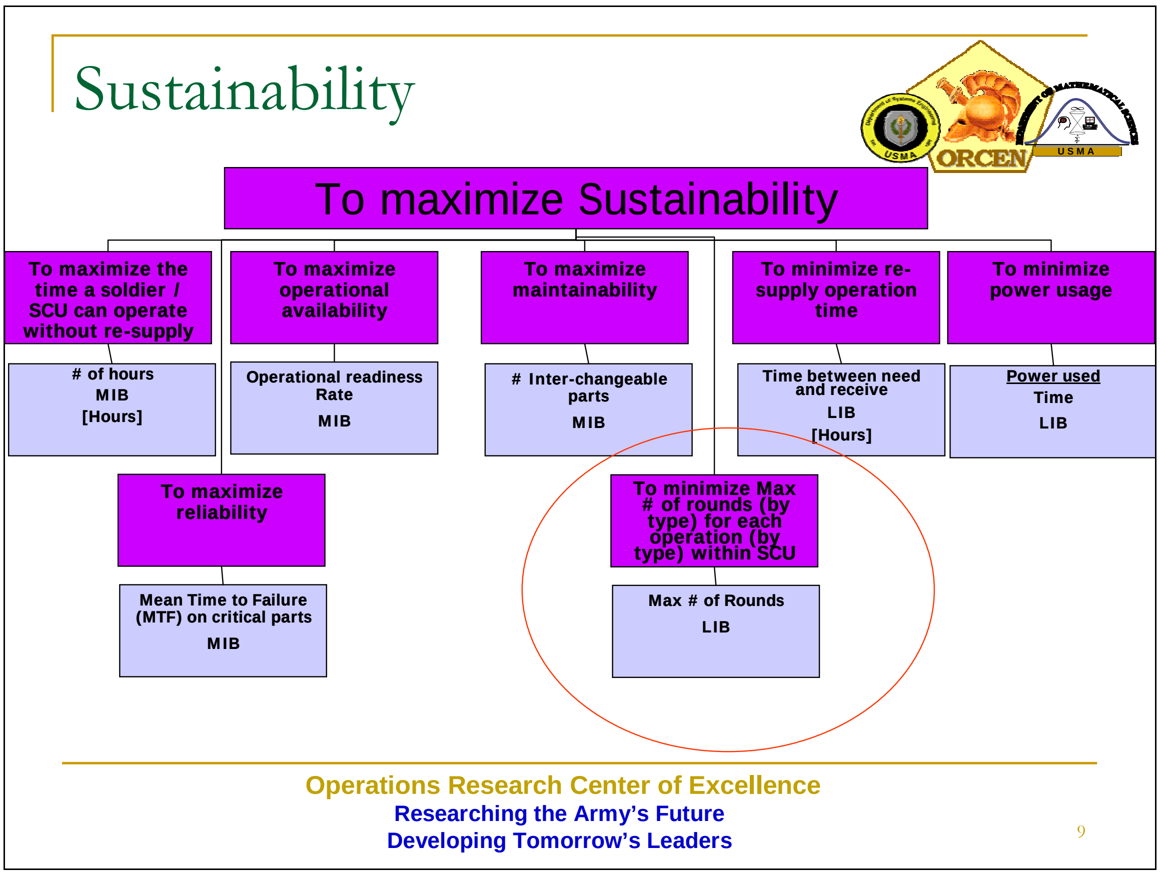


Figure 1: Focus area for Sustainability input discussion identified in hierarchy

Input from Group Systems Work:

- Accuracy of knowledge of actual ammo status across the SCU
- Should be: To minimize Max # of rounds (by type) required for each operations (by type) within the SCU
- have fewer number of total parts
- Other classes of supply - water, food, etc
- maximize the lethality and accuracy of ammunition type
- knowledge of rate of usage
- I'm not sure we want to minimize ammo; different ammo is needed for different targets; gives the SCU more capability
- knowledge of availability of supplies from the provider
- how many cables are common and how many are unique
- minimize need for depot repair req'ts.
- how many repairs can be made by the operator vice a repair MOS
- avg duration of components
- Maximize availability of organic load assist systems (mules)
- software interchangeability - squad leader, team leader, etc
- how many repair tools are required? who has these tools?
- To maximize maintainability - Measure time for Soldier to perform operator maintenance
- # of Load carriage system failures by duty position
- load carriage capacity
- amount of time need to prevent component failure

2. Mobility

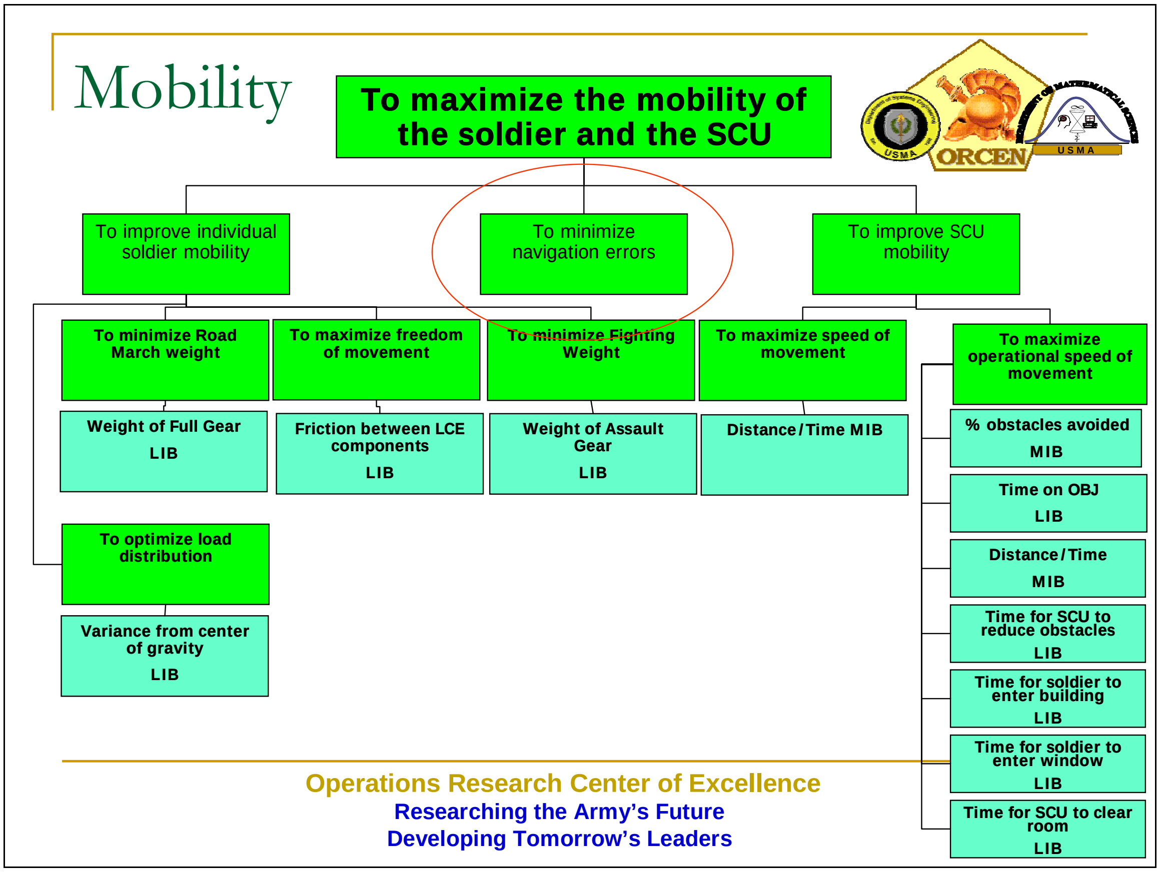


Figure 2: Focus area for mobility input discussion identified in hierarchy

Input from Group Systems Work:

- Count the actual number of navigation errors
- when is the dead reckoning module functioning in lieu of the GPS
- how many satellites is the GPS reading
- Deviation RMS - Root mean square
- Difference (deviation) between planned and actual
- maximize low light level vision capabilities
- how does the leader control movement? is there a point man? how does he know where to go?
- Time to reach planned objective
- Nav Errors: minimize time spent enroute (how well Soldier avoids "aimless wandering")
- rate of deviation/time
- how does night navigation compare to day navigation
- are planned routes the best routes?
- avg deviation over distance
- minimize location - position error of the system
- Min time, max position accuracy i.e. position acc/time ratio

- It might be helpful again to define what we think mobility consists of - What are the elements of mobility?
- how are accurate are the maps being used?
- Do an experiment on a navigation course and see how well FFW soldiers do compared to non-FFW soldiers
- Physiological cost - heart rate, respiration rate, BP,
- Deviation from a the waypoints of a defined route
- Measure weight carried by soldiers
- # of rest breaks required over distance covered
- physiological condition of soldiers when objective is reached
- Run a land navigation course using digital waypoints - not signs in the woods
- Measure the distance from the surveyed waypoint & the location of the Soldier when his GPS tells him he has reached the waypoint (Surveyed GPS location)

3. Lethality

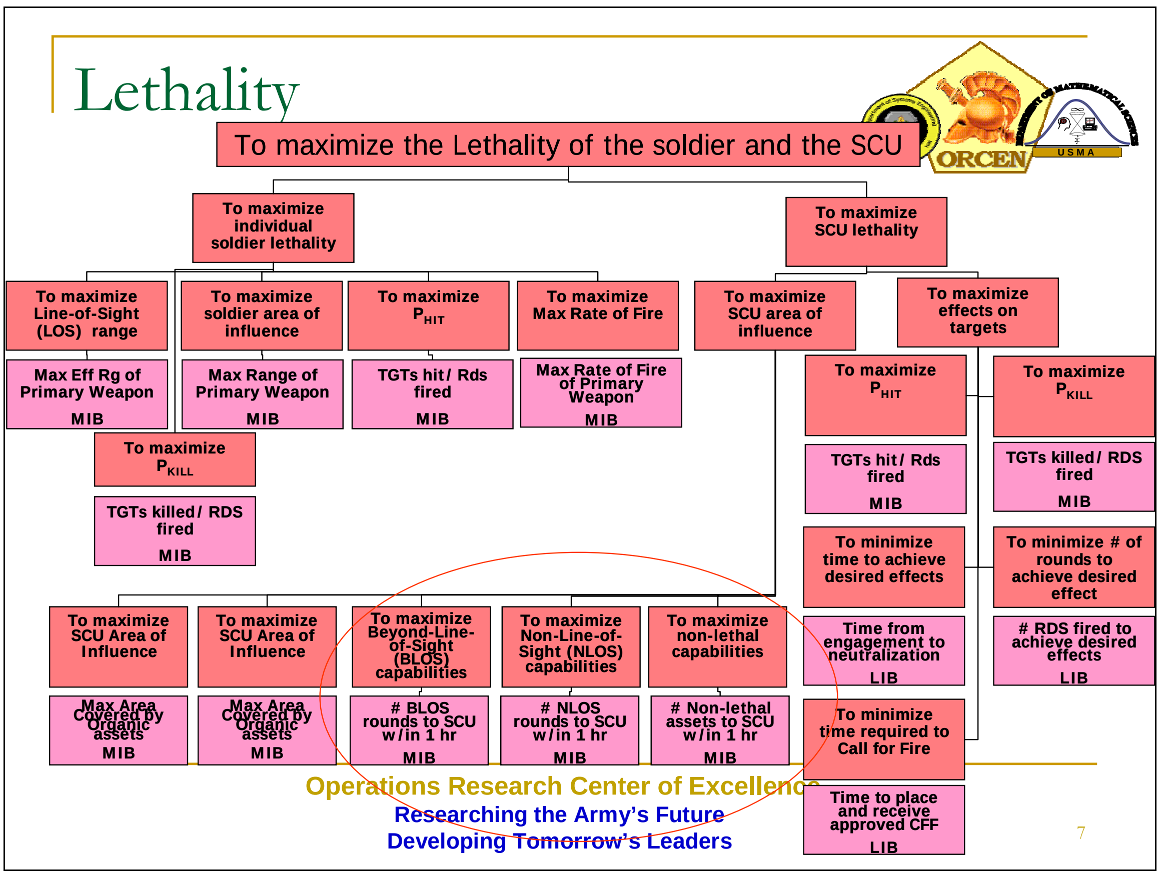


Figure 3: Focus area for lethality input discussion identified in hierarchy

Input from Group Systems Work:

- to maximize area of influence for the SCU we need to consider sensor coverage as well as weapon

- area of influence is also a function of netted fires, most of which are not organic and must be task organized
- UA O&O states that a platoon's area of influence is 8km radius
- % of time the correct weapon is used for effects
- % organic BLOS rounds used to achieve desired effects
- Time to receive threat target information from non-organic information sources on targets detected within the SCU's area of influence
- BLOS: number of targets not engaged when BLOS is not available, which are engaged when BLOS is available
- SCU AoI - Target density (targets/area)
- - Targets/time
- To maximize SCU Area of Influence #1 (bottom level): Should be - To maximize SCU area covered by organic assets
- enemy casualties per SCU watt hours consumed in the engagement
- avg weapon coverage/duty position
- measure total area of assigned sector as a percentage of max possible area of influence
- BLOS - The range that a successful kill is affected by sensor
- Distance between squads during mission
- Distance between fire teams during mission
- range of sensor to target
- To maximize SCU area of influence #2 (bottom level): Should be - To maximize Area covered by in-organic assets
- Time to react to a threat within the SCU's area of influence - For example a threat that is several kilometers away from the SCU, but still within its area of influence
- NLOS: number of targets engaged by NLOS which are not otherwise engaged
- It might be helpful to define what we think lethality consists of - what are the elements of lethality
- I see probability of hit on the lethality chart, but do not see probability of detection - Should it be there?

II. Info Superiority
Common Combat Experimentation and Sim MOP (Topic Commenter)

Initially Suggested MOP
1. 1. Average percentage of enemy force identified by friendly forces aggregated over time.
2. Average percentage of friendly force identified by friendly forces aggregated over time.
3. Average time delay in receiving enemy and friendly force identification information (aggregated).
4. Fratricide - number of friendly forces killed by friendly forces.

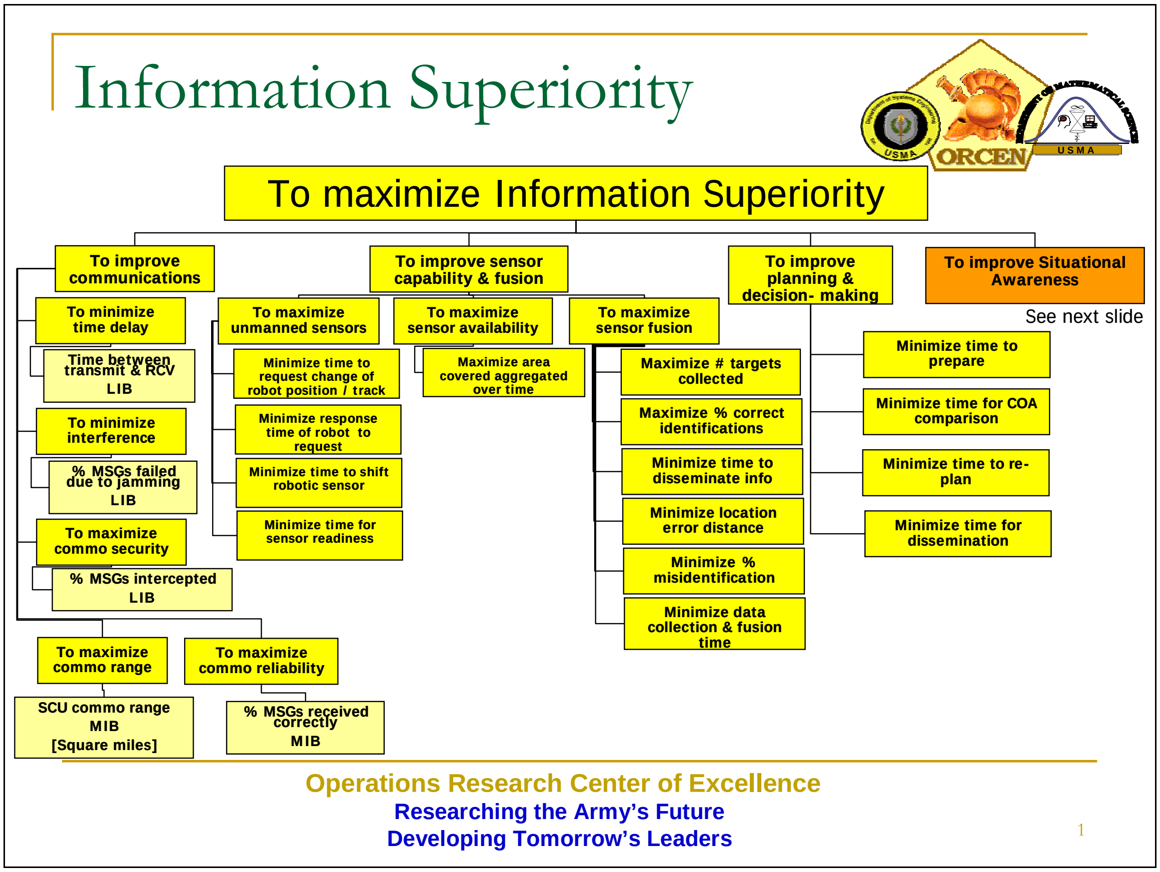


Figure 4: Current Information Superiority MOP Hierarchy

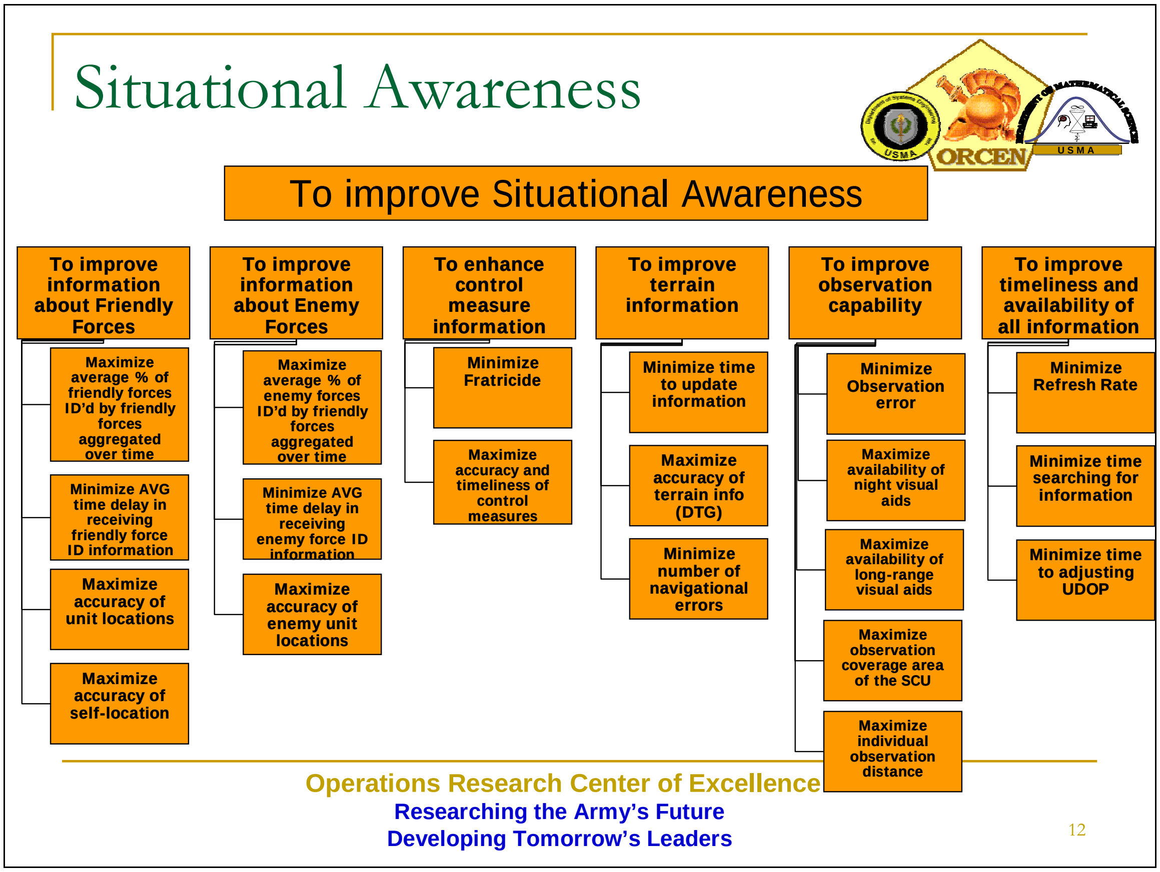


Figure 5: Current Situational Awareness MOP Hierarchy

Input from Group Systems Work:

- amount of supplies consumed
- amount of power consumed
- time to identify threats
- time to disseminate threat information
- proportion of targets defeated that are high-payoff targets
- how much situational awareness is really needed? how much situational awareness is too much?
- who gets what SA?
- I like the 4 that are already included.
- SCU sensor range and area of coverage
- time to complete mission
- distance traveled by scu from start of mission to end
- distance between squads during mission
- Average amount of bandwidth aggregated over time
- distance between fire teams during mission
- Is distance between squads & fire teams a MOP or an Analysis Factor?
- total time comms devices used by duty position during mission

- are the "forces" identified, either the enemy or friendly, the most important forces to be aware of? are they in your sector or within your area of influence?
- # of messages received by duty position during mission
- There seems to be two categories of MOP. One is the MOP that relate to SCU operational effectiveness & another set that relate to system design.

III. Sustainability
Common Combat Experimentation and Sim MOP (Topic Commenter)

Initially Suggested MOP
1. 1. Amount of time that the SCU can operate without resupply. This is the minimum of any critical supply item sustainment duration.
2. Maximum soldier battery power required within the SCU.
3. Maximum number of rounds (by type) required within the SCU.

See Figure 1 for current Sustainability MOP Hierarchy

Input from Group Systems Work:

- Ability to redistribute capability across the squad within all physical and environmental constraints
- Average amount of energy consumed by position (Platoon leader, squad leader, rifleman, etc)
- efficiency of the use of rounds, i.e. number of rounds expended as a function of the number of enemy killed
- For number 2 & 3, you don't need the word "maximum"
- soldier energy (electrical) consumption for the mission
- The word "Maximum" needs to be removed in the 2 bullets -
- The 3 are possible in experiments
- minimize time system unavailable for energy
- were ammo and power cross-leveled during the mission?
- Mean time between mission critical failures
- Minimum critical functions that can be included in all soldier variants in the squad
- did any Soldier completely expend his available ammo or power?
- Max energy used / duty position
- Average number of rounds expended by weapon system
- peak energy / duty position
- peak energy / capability
- Minimize standard deviation of task loading of individual soldiers in the squad
- operation duration of robotic asset for mission
- Average amount of energy consumed by energy consuming components, sub-systems, systems within the SCU
- # of batteries used in mission
- Average number of batteries used by position
- # of mission failures by device

- Average number of batteries used by components, sub-systems, systems requiring batteries
- optimum ammunition distribution by position and type of ammunition
- % mission failures when squad is supply limited
- watt hours consumed per capability per enemy casualties (e.g., power consumed by a particular subsystem that is critical for a particular operational capability; e.g., DRS weapon sight to support SCU BLOS. Is the power draw of the capability/component worth the operational payoff?)

IV. Mobility
Common Combat Experimentation and Sim MOP (Topic Commenter)

Initially Suggested MOE:
MOE is time to complete the mission.

See Figure 2 for current Mobility MOP Hierarchy

Input from Group Systems Work:

- Time per load
- does the unit ever unintentionally halt due to lack of mobility?
- minimize fighting load weight
- minimize assault load weight
- does the rate of movement fluctuate greatly?
- maximum rate of movement
- NOTE: we need to improve the ABILITY to move rapidly, even if that ability is not needed for a given part of a mission
- ability to move quickly/quicker than baseline for the SCU and individual soldier movement rate
- does FFW system provide speed and agility advantages over current culminating in reduced mission time
- time to complete troop movements to achieve netted fires synchronization by the SCU

V. Training
Measures that are best addressed with methods other simulation or combat scenario experimentation (Topic Commenter)

Initially Suggested MOP:
1. Percentage of critical individual tasks covered with embedded training capability.
2. Percentage of collective tasks covered with embedded training capability.
3. Average time required to gain proficiency.

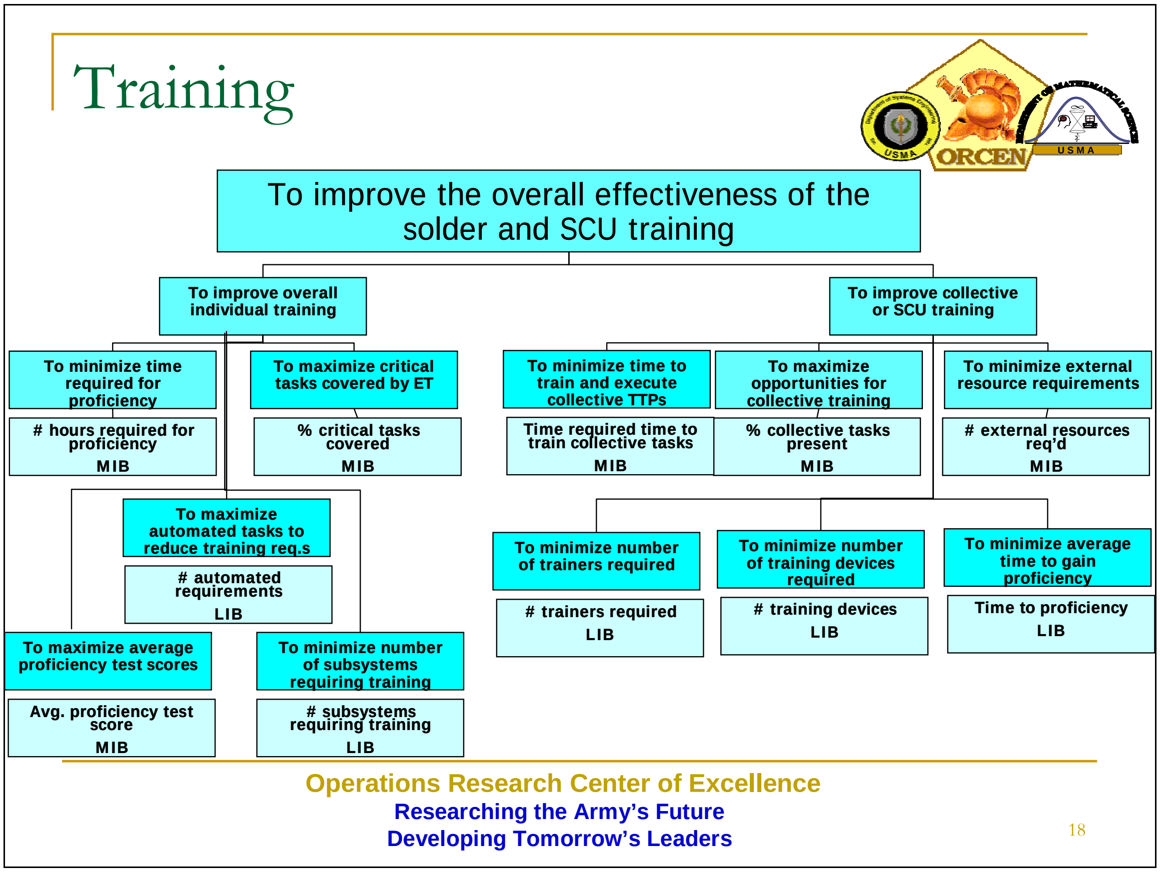


Figure 6: Current Training MOP Hierarchy

Input from Group Systems Work:

- Training MOPs are not modeled in our simulations
- is there any training decay for critical tasks for time?
- power required to train on individual/collective task using FFW embedded training
- Time required to complete the mission
- Is the training effective?
- Time to use an embedded training tool
- time to complete each specific collective task during mission
- time to train Soldier on UDOP usage
- Time to complete a task that a Soldier used an embedded training tool to refresh himself on
- #1 and #2 are simply a manual count of system capabilities, should not require experimentation or simulation
- The consistency with which set missions are repeated successfully by the same, or different squads

VI. Flexibility and Interoperability

Measures that are best addressed with methods other simulation or combat scenario experimentation (Topic Commenter)

Initially Suggested MOP:
1. Number of operational scenarios within which the FFW-equipped SCU can successfully operate (consider mission and environment).
2. Number of external systems with which the FFW-equipped SCU is interoperable (consider communications, power, supplies, size, and weight requirements).

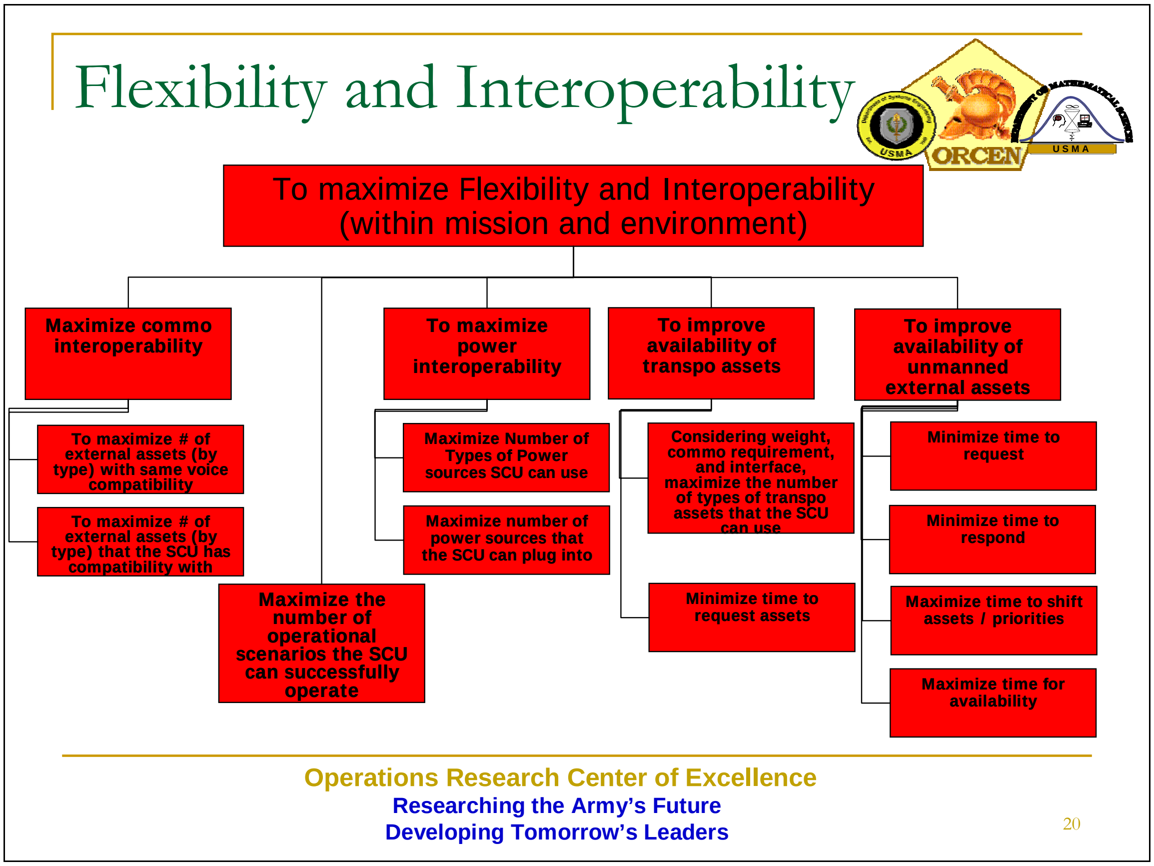


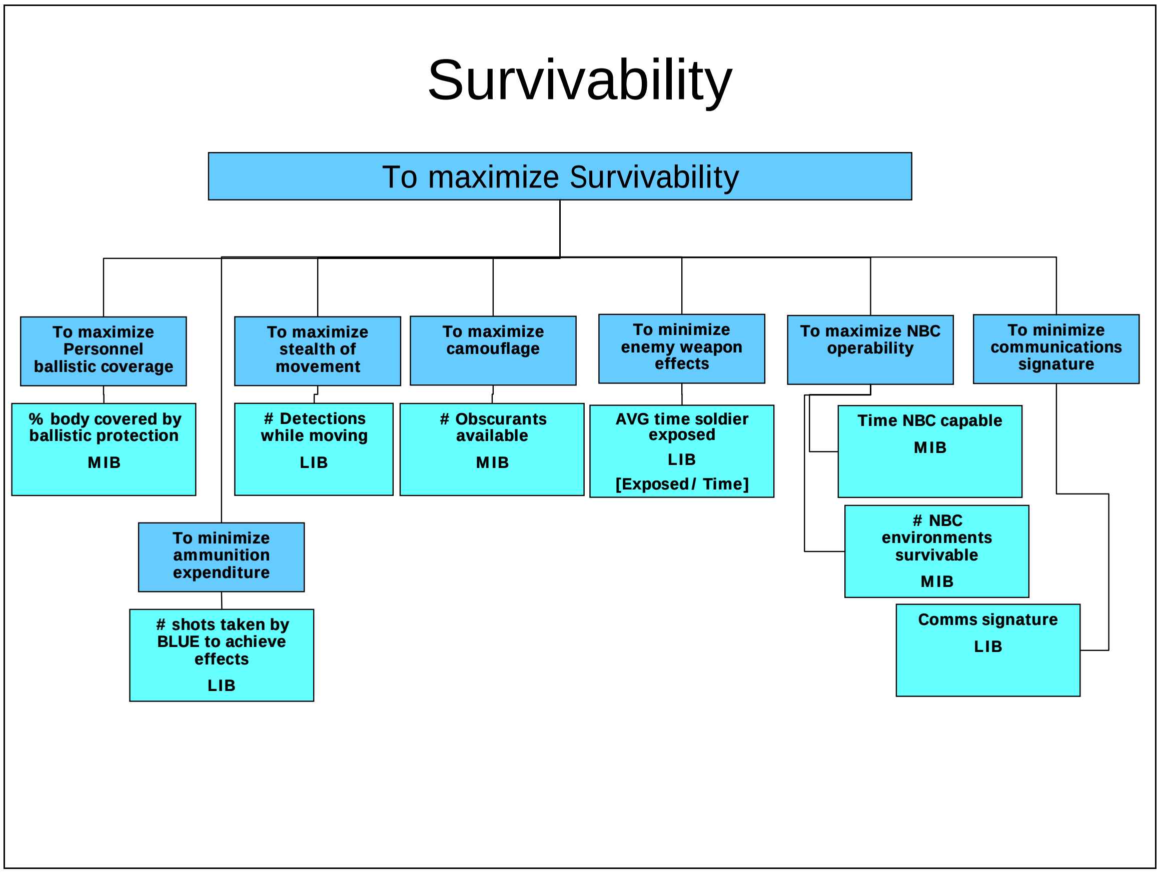
Figure 7: Current Flexibility and Interoperability MOP Hierarchy

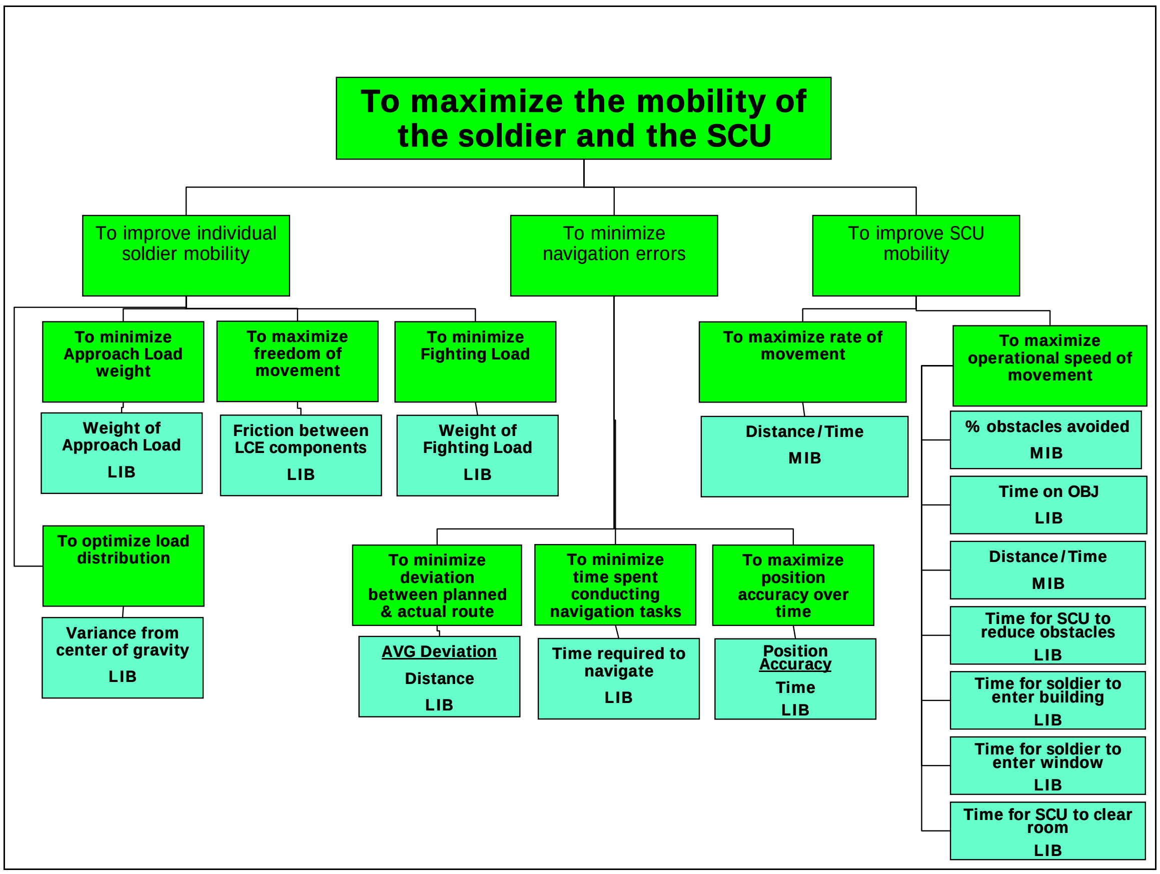
Input from Group Systems Work:

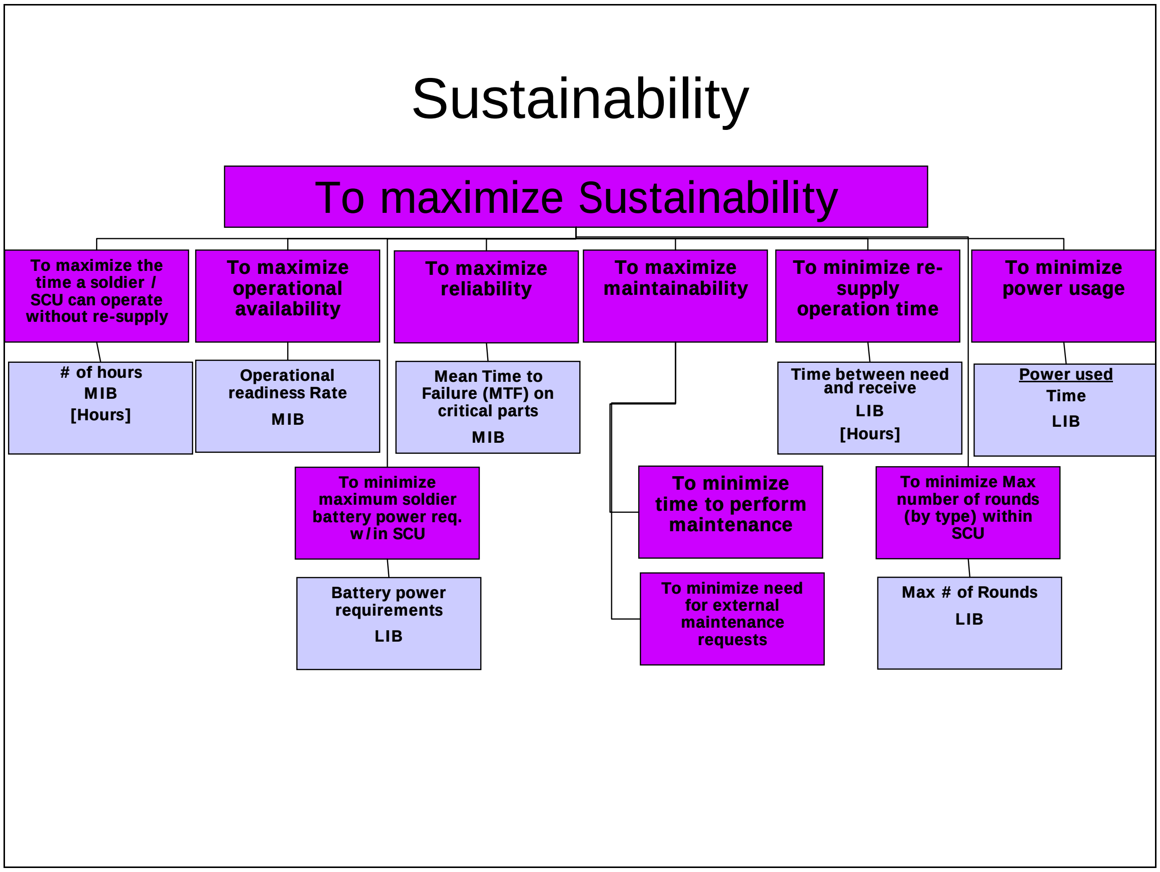
- how seamless is task organization for a mission? can new attachments operate within their new command?
- Simulation could capture #1 number of opnl scenarios that FFW SCU could do
- do security issues such as commo keys and rights, roles, and privileges prevent interoperability?
- Success at achieving a mission type for which training has not been provided
- Interoperability & flexibility is probably best suited for analysis using live experimentation or other types of user feedback events
- Interoperability addresses message passing, therefore we need to measure that messages are formatted by FFW to get from/to high units

- can FFW simulate info transmit and receive to/from SCU and external systems to stimulate FFW live experiments?
- measure advantage of vehicle battery recharge capability in terms of mission extension
- #2 is largely an engineering design issue, although simulation is addressing energy, supplies, and weight requirements
- Should we include "Maximize Lethality Interoperability?"
- Success in successfully completing a new mission type with an external force for which minimum training has been received

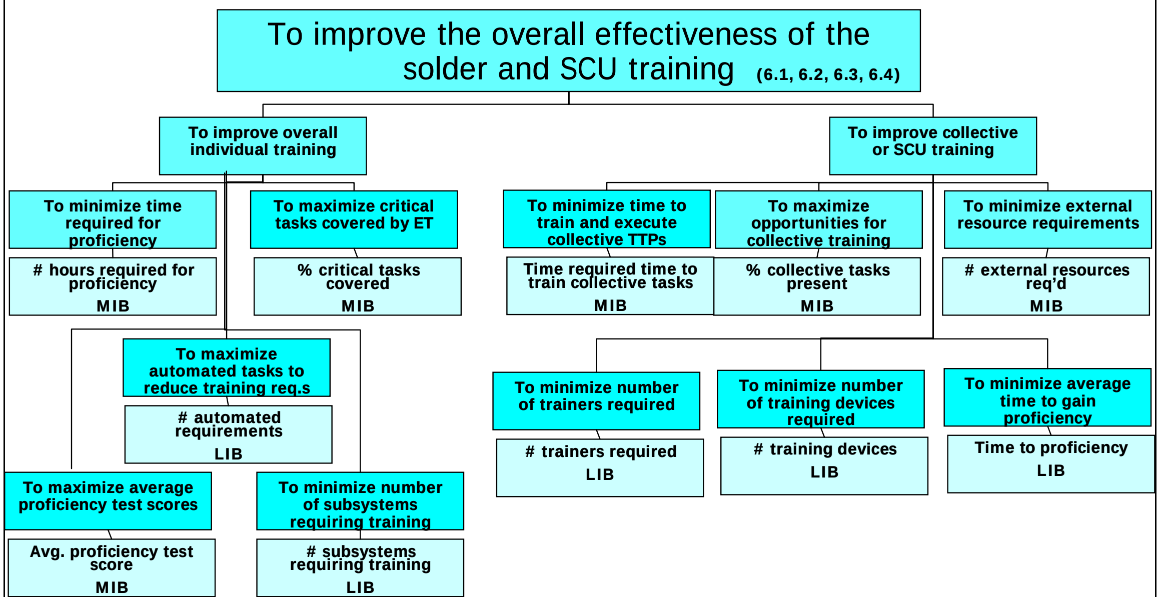
Appendix B: MOP Hierarchy for Survivability, Mobility, Sustainability, Training, Flexibility & Interoperability, and Cost



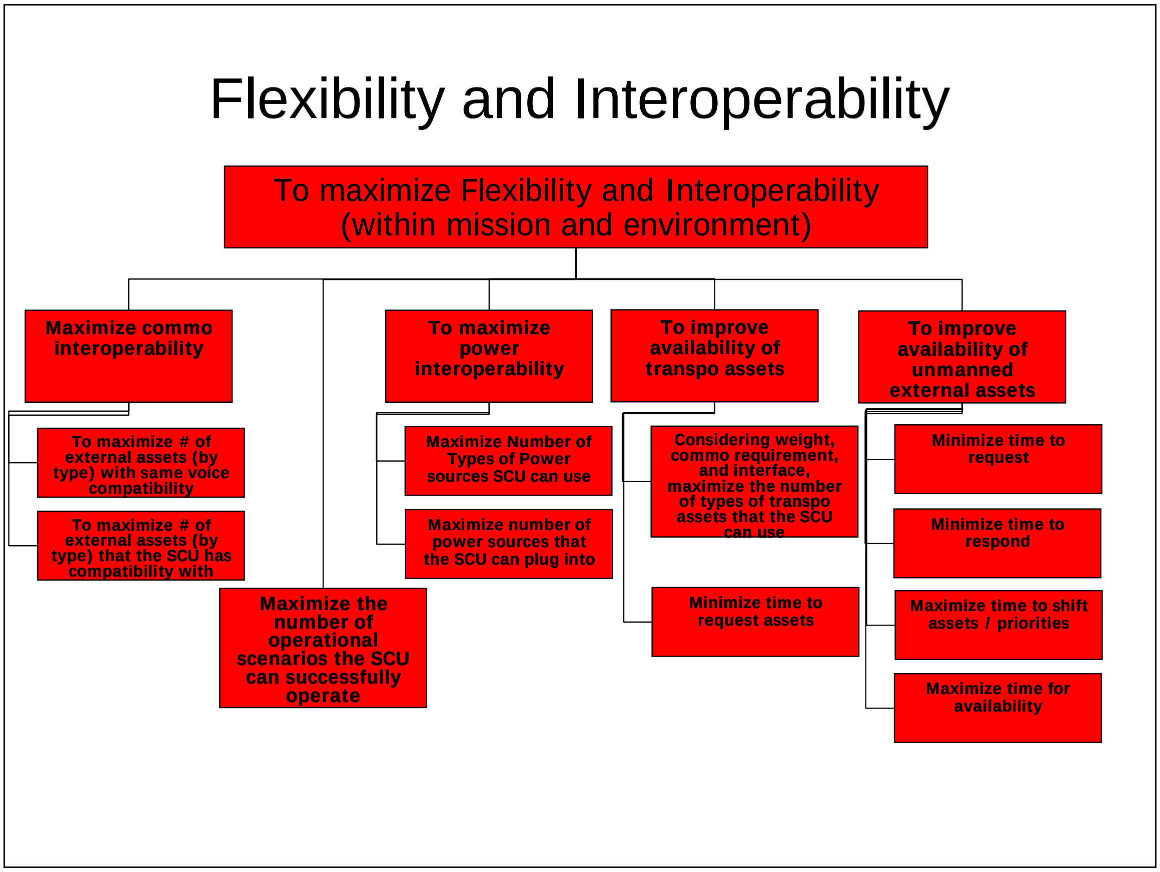

To maximize the mobility of the soldier and the SCU
To improve individual soldier mobility
To minimize navigation errors
To improve SCU mobility
To minimize Approach Load weight
Weight of Approach Load
LIB
To maximize freedom of movement
Friction between LCE components
LIB
To minimize Fighting Load
Weight of Fighting Load
LIB
To optimize load distribution
Variance from center of gravity
LIB
To minimize deviation between planned & actual route
AVG Deviation
Distance
LIB
To minimize time spent conducting navigation tasks
Time required to navigate
LIB
To maximize position accuracy over time
Position Accuracy
Time
LIB
To maximize rate of movement
Distance/Time
MIB
To maximize operational speed of movement
% obstacles avoided
MIB
Time on OBJ
LIB
Distance/Time
MIB
Time for SCU to reduce obstacles
LIB
Time for soldier to enter building
LIB
Time for soldier to enter window
LIB
Time for SCU to clear room
LIB

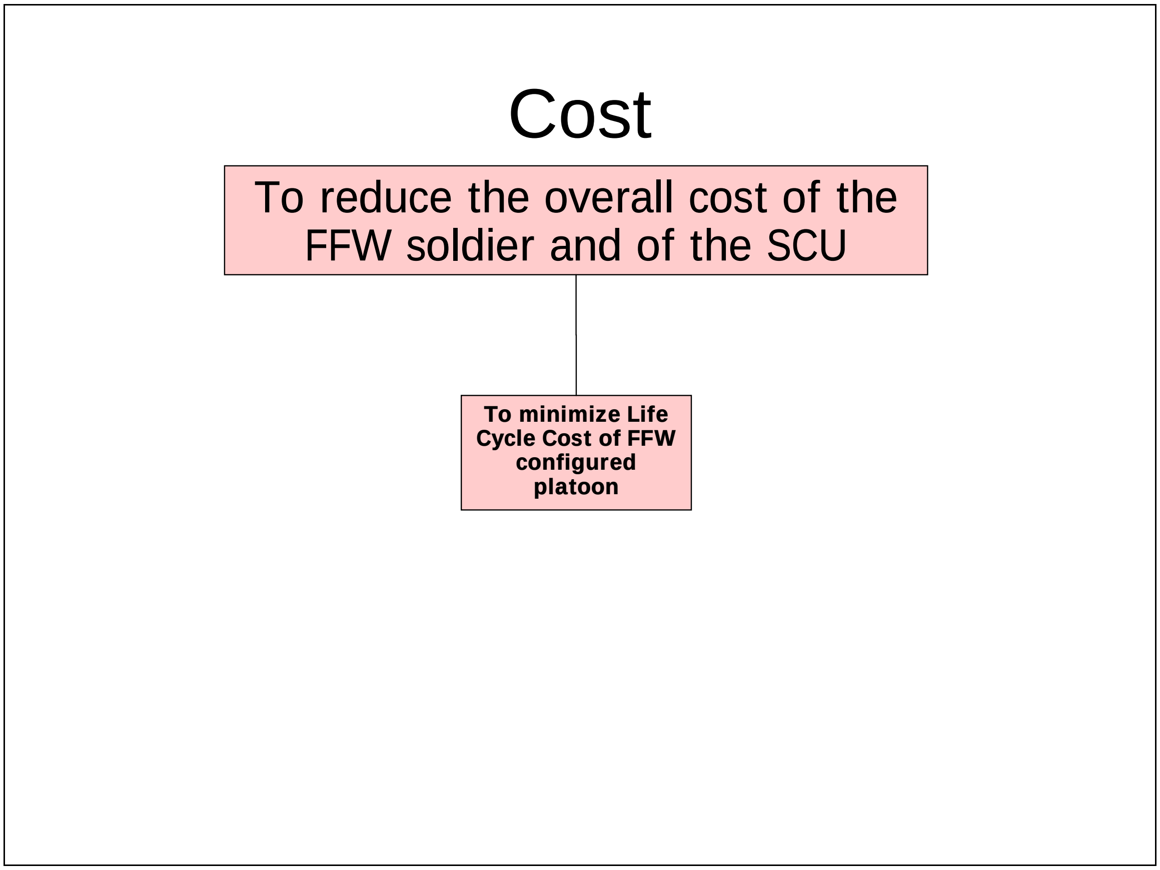

Sustainability
To maximize Sustainability
To maximize the time a soldier / SCU can operate without re-supply
To maximize operational availability
To maximize reliability
To maximize maintainability
To minimize re-supply operation time
To minimize power usage
# of hours
MIB
[Hours]
Operational readiness Rate
MIB
Mean Time to Failure (MTF) on critical parts
MIB
Time between need and receive
LIB
[Hours]
Power used
Time
LIB
To minimize maximum soldier battery power req. w/in SCU
To minimize time to perform maintenance
To minimize Max number of rounds (by type) within SCU
Battery power requirements
LIB
To minimize need for external maintenance requests
Max # of Rounds
LIB

Training



To improve the overall effectiveness of the solder and SCU training (6.1, 6.2, 6.3, 6.4)
To improve overall individual training
To improve collective or SCU training
To minimize time required for proficiency
hours required for proficiency
MIB
To maximize critical tasks covered by ET
% critical tasks covered
MIB
To maximize automated tasks to reduce training req.s
automated requirements
LIB
To maximize average proficiency test scores
Avg. proficiency test score
MIB
To minimize number of subsystems requiring training
subsystems requiring training
LIB
To minimize time to train and execute collective TTPs
Time required time to train collective tasks
MIB
To maximize opportunities for collective training
% collective tasks present
MIB
To minimize external resource requirements
external resources req'd
MIB
To minimize number of trainers required
trainers required
LIB
To minimize number of training devices required
training devices
LIB
To minimize average time to gain proficiency
Time to proficiency
LIB


Flexibility and Interoperability
To maximize Flexibility and Interoperability (within mission and environment)
Maximize commo interoperability
To maximize # of external assets (by type) with same voice compatibility
To maximize # of external assets (by type) that the SCU has compatibility with
Maximize the number of operational scenarios the SCU can successfully operate
To maximize power interoperability
Maximize Number of Types of Power sources SCU can use
Maximize number of power sources that the SCU can plug into
To improve availability of transpo assets
Considering weight, commo requirement, and interface, maximize the number of types of transpo assets that the SCU can use
Minimize time to request assets
To improve availability of unmanned external assets
Minimize time to request
Minimize time to respond
Maximize time to shift assets / priorities
Maximize time for availability


Cost
To reduce the overall cost of the FFW soldier and of the SCU
To minimize Life Cycle Cost of FFW configured platoon

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14. ABSTRACT

As an important part of the Future Force Warrior (FFW) program, the Analysis and Experimentation Team (A&ET) performs Systems of Systems (SoS) modeling, closed-loop simulation, Soldier in the Loop (SITL) simulation, virtual simulation, and live experimentation analyses. Within the A&ET, the Analysis Team is directly responsible for these SoS efforts short of live experimentation and demonstrations. The analysis efforts must be integrated into a larger A&ET strategy that supports FFW design and development decision making. This work provides a methodology for developing primary Measures of Performance (MOP) and Measures of Effectiveness (MOE), an Integrated Analysis and Experimentation Framework, and an Analysis and Experimentation Event Plan. The methodology and the resulting tools were developed to support the Design, Build, and Integration Phase of the FFW program. However, the general methods and techniques are intended to be useful for other Science & Technology (S&T) and acquisition programs.

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